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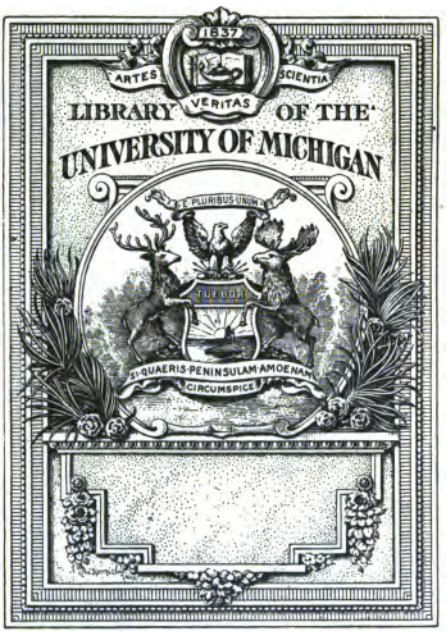

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CHEMICAL RECREATIONS:

A Popular Manual

OF

EXPERIMENTAL CHEMISTRY.

BY JOHN JOSEPH GRIFFIN,

FELLOW OF THE CHEMICAL SOCIETY,

HONORARY MEMBER OF THE PHILOSOPHICAL SOCIETY OF GLASGOW.

THE TENTH EDITION.

FIRST DIVISION:

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PREFACE.

THIS work is offered as a Manual of Experimental Chemistry for the use of beginners. The author has two classes of readers particularly in view, namely, Students attending Lectures or Lessons on Chemistry, and Schoolmasters who desire to teach the Elements of Chemistry, in Popular Lectures or Experimental Lessons. Both of these classes of readers will find useful information in the following pages. The author has endeavoured to elucidate most effectively those subjects which urgently demand the notice of beginners. Thus, he has given ample accounts of Air, Water, Earths, Acids, Useful Metals, and Common Salts, while subjects of less importance are passed unnoticed.

The experiments selected to illustrate the subjects fixed upon are striking and convincing, and such as can be performed with facility and economy. The precautions necessary to ensure success and safety are detailed, and, as far as possible, the experiments are *exhibited* by means of numerous figures of apparatus, many of which represent new and simplified instruments, specially intended to aid the researches of young chemists. This is particularly the case with apparatus adapted to micro-chemistry, or the art of experimenting on minute quantities.

The chapters describing Elementary Experiments are written in a peculiar style, to show in what manner the elements of practical chemistry can be taught to large classes of students in schools. The chapter on the "Qualitive Analysis of Salts" is a sequel to the elementary experiments. It is an Introduction to Analysis for the use of *very* young chemists. After mastering these chapters, the reader will easily comprehend the use of the Tables of Tests given in subsequent chapters of the work.

The TABLES will be found to contain a mass of useful information, conveyed, I hope, intelligibly.

The experimental portion of the work is not confined to chemical recreations or to experiments of demonstration, but includes much information relating to analytical processes. In particular, it embraces an account of a new method of preparing test liquors of fixed strength, and of applying such liquors, by means of graduated decimal measures, to the rapid analysis of acids, alcalies, and salts. This method of testing is equally useful to students of chemistry and to persons professionally engaged in the chemical arts. Among the applications of which it is susceptible, is that of determining the strength and purity of chemical preparations used in medicine.

The author has the pleasing task of expressing his gratitude for the favourable reception accorded to nine preceding editions of this work;

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and, on presenting the TENTH EDITION, which he has endeavoured to render worthy of continued patronage, he indulges in the hope that it will still be found entitled to rank with books of practical utility.

The work will be published in THREE DIVISIONS :—

I. ELEMENTARY EXPERIMENTS.—General Doctrines of the Science; Introduction to Analysis; Chemical Manipulation; Centigrade Testing; Tables.

II. THE METALLOIDS and their Combinations with one another; Air; Water; The Gases; The Acids.

III. THE METALS and their Compounds.

LONDON, *December*, 1853.

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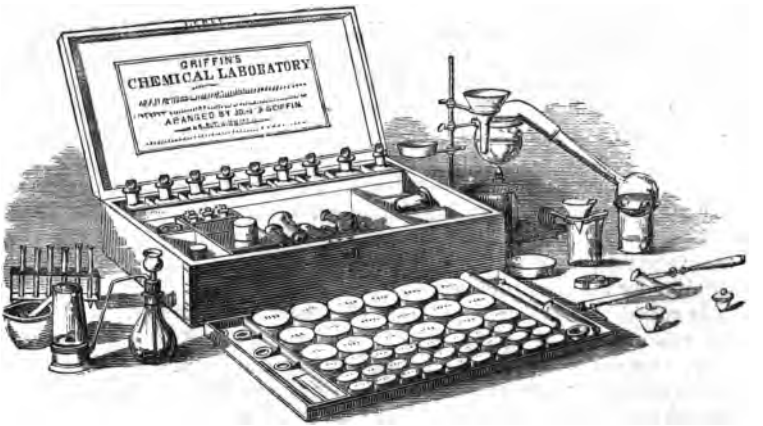

INTRODUCTION.

CHEMISTRY is the science which makes known to us the properties of the component particles of all natural bodies. It treats of the *various sorts* of substances, and of the exact determination of their differences. It exhibits the means by which the component parts of compound bodies can be separated from one another, or by which the elements of compounds can be made to combine together. In fine, it shows by what contrivances the solid particles which constitute the material substances of the world can be most beneficially applied to the service of man.

The objects of Chemistry are inexhaustible. It undertakes the examination of all bodies which act upon the senses, the solid matter of all animal, vegetable, and mineral substances. It seeks to determine the properties of those substances, the number and proportion of their component particles, the individual nature of those components, and the properties of all other compounds which can be produced by their combination. So infinitely varied are the objects of Chemistry that it is an everlasting source of occupation and amusement; and while, on this account, it receives the attention of the philosopher, it claims the notice of all men, from its utility in the arts which promote and support the comforts and existence of civilized life.

The great importance of the science of Chemistry is rendered evident by the following considerations:—It is useful in explaining natural phenomena: for in determining the constitution of the atmosphere, in investigating the changes to which it is subject, the variations

of temperature, the laws of winds, dew, rain, hail, and snow, Chemistry is our only satisfactory guide. These remarkable changes in the face of nature—changes which, because familiar, do not produce any emotion in the mind, though in themselves truly wonderful—are chemical operations on a magnificent scale, and can only be explained by chemical laws.

In man's researches into the nature of the things whence he derives the means of his comfort, his happiness, his luxuries, and even his existence—in examining the various objects which compose the mineral, the vegetable, and the animal kingdoms—Chemistry is essentially requisite for the successful progress of his inquiries.

In considering the application of Chemistry to the improvement of the arts of civilized life, a wide field of contemplation opens to our view. So extensive, indeed, are its influence and importance, that, in most of the arts, many of the processes—in some all that are employed, depend on chemical principles. The bare mention of some of these arts will suggest ample illustrations of its extensive utility.

In the medical art, so great is the service of a knowledge of Chemistry, that its practical acquisition is now universally regarded as an essential branch of a medical education. In agriculture, recent chemical researches have established principles that promise to be followed by results of extraordinary benefit to mankind. In the art of extracting metals from their ores, in purifying and combining them with each other, and in forming instruments and metals—whether for useful or ornamental purposes—almost all the processes are purely chemical. The arts of glass and porcelain making, of tanning, soap-making, dyeing, and bleaching, depend entirely upon Chemistry; and all the processes in baking, brewing, and distilling, most of the culinary arts, and many other processes in domestic economy, are chemical operations. In short, wherever, in any of the processes of nature or of art, the accumulation or the diminution of heat takes place—wherever a sensible change is to be effected by heat—wherever substances in combination are to be separated—wherever the union of simple substances and the formation of new compounds are to be effected—the operations and their results can only be explained on chemical principles.

From this general view of the extensive applications of chemical science to the arts, those who have not considered the objects which it embraces will be enabled to judge of the importance of this study.

Reasons why Chemistry should become a stated Branch of Education.—If we consider Chemistry purely as a science, we shall find no subject better calculated to encourage that generous love of truth which confers dignity and superiority on those who successfully pursue it. There is no science which holds out more interesting subjects of research, and none which affords more striking proofs of the wisdom and beneficence of the Creator of the universe.

A machine constructed by human art, is admired in proportion to the simplicity of its contrivance, to the extent of its usefulness, and to the niceness of its adaptations. But the works of man sink into nothing when brought into comparison with the works of nature. When we examine the former, every step of our progress is obscured with comparative clumsiness and defect: in contemplating the latter, we behold perfection rise on perfection, and more exquisite wonders still meeting our view. It is the merit of Chemistry, that by its aid we are enabled to take a minuter survey of the great system of the universe. And we find, so far as our limited powers can comprehend it, that the whole is nicely balanced and adjusted, and that all its changes tend to the most beneficial purposes. Circumstances which, on a superficial view, were seeming imperfections and defects, a closer inspection points out to be real excellencies. In all the singular and surprising changes which everywhere present themselves, the more closely we observe and examine them, the more do we admire the simple means by which they are accomplished, and the intelligent design and perfect wisdom displayed in the beneficial ends to which they are directed.

To these considerations respecting the importance of Chemistry, we may add another, which, at a period when this science is taking its proper place in schools as a branch of general education, is not without its interest. This consideration is, that Chemistry is a subject qualified to train both the *mind* and the *hands* of young people to habits of industry, regularity, and order. It teaches the doctrine that accurate and extensive observation is necessary for the accumulation of facts; that careful and exact comparison is necessary for the reduction of these facts to general statements; that logical precision is necessary in estimating the relative value of various problematical statements on points where positive information is wanting; that, consequently, the chemist must study to become capable of judging according to *circumstantial evidence*, and in that manner habituate himself to the formation of sound opinions on all subjects that come under his cognizance. If any one will consider the great value of a sound judgment in the ordinary affairs of life, he cannot but appreciate the strength of this argument in favour of a chemical education.

Again, the necessity of observing the most scrupulous and constant regard to *cleanliness* in experimenting, as being indispensable to success, must gradually induce habits of neatness and cleanliness even in the most slovenly; while the equally unavoidable necessity of carrying on the different steps of an operation in an orderly and cautious manner, must have a corresponding moral influence upon persons of the most careless disposition.

Independently, therefore, of any advantages to be hoped for from the possession of the mere facts of Chemistry, setting entirely out of view the applications, either of the principles or the details of the science to

the prospective commercial, or scientific, pursuits of the young student, there is, in the mental and moral discipline which its study affords, high inducements for making Chemistry a branch of general education.

METHODS OF CHEMICAL RESEARCH.—It has been demonstrated by the experiments of chemists, that the marvellous diversity of appearance under which bodies are presented to the eye, and the unceasing changes to which they are subject, are occasioned by the mutual reactions of a small number of unchangeable elementary particles. The distinctive properties of these particles, the nature of the phenomena which mark their reactions, the methods of causing them to combine, the properties of the resulting compounds, and the methods of decomposing these compounds,—are, consequently, the objects which the chemical student is called upon to investigate.

There are two methods of proceeding in the acquisition of chemical knowledge; these are called *analysis* and *synthesis*. ANALYSIS means the art of *separating* the constituents of compound bodies,—SYNTHESIS, the art of forming compounds, by the *putting together*, or effecting the *combination*, of their component particles. Both analysis and synthesis are practically effected by the performing of certain processes or operations, thence called *chemical operations*.

The properties of natural bodies, whether they be simple or compound, native or factitious, can never be determined *à priori;* they can be discovered only by *actual trial*. When an unknown substance is presented to a chemist for examination, he submits it to certain *trials*, or performs certain *operations* upon it. He examines, for example, the relation of the unknown body to heat, light, water, acids, alcalies, and other liquids. These *trials* have particular *names* given to them, for the sake of convenience in the communication of knowledge. If a substance is exposed to a *red heat*, the operation is termed IGNITION. If the substance *melts*, the operation is termed FUSION. If the substance, on being put into water, *dissolves* or *disappears*, the operation is termed SOLUTION, and the resulting liquid is called *a solution*. If the solution is exposed to heat so as to cause the water to rise *in vapour*, the operation is termed EVAPORATION; or if the operation is so performed that the vapour is collected and reconverted into water, the operation is termed DISTILLATION. If, on the contrary, the solution, instead of being exposed to evaporation, is mixed with some liquid which causes the production of a *solid substance* or powder, the operation is called PRECIPITATION; and if means be taken to separate the solid powder from the residual liquid, by straining through a porous substance, this operation is termed FILTRATION.

The performance of these operations communicates to the chemist a certain degree of knowledge respecting the properties of the substance operated upon. If the substance does not melt when exposed to a strong degree of heat, it is said to be *infusible*. If it does not dissolve

when placed in a liquid, it is said to be *insoluble*. A description of the results of a series of such experiments, is the chemical character of the substance. We cannot account for the properties thus found to belong to a substance. No chemist can go farther than the ascertainment of simple facts. The sagacity of man is insufficient to determine WHY a given substance is soluble or insoluble, fusible or infusible. The *nature of the power* which causes fusion or solubility is unknown. And, indeed, this is the case with regard to all physical phenomena: *the forces which produce them are unknown to man, except by their effects.*

The more numerous the operations performed upon a substance, the more accurate is the knowledge acquired respecting its properties: provided the operations be suitably conducted. The properties of a substance can never be wholly known. Chemists begin with a single fact; their daily experience enlarges their knowledge: but, at the best, their acquaintance with the properties of any one body is but limited and imperfect. Not until a substance shall have been submitted to the action of every other substance, and under all possible variations of temperature, pressure, and so forth, will its properties be wholly determined; and that will *never be*. The knowledge we possess respecting the properties of known elements and their compounds, is, notwithstanding the labours of many industrious chemists, still extremely imperfect. No practical chemist, however young he may be in the science, can pursue his studies with even a moderate degree of zeal, without being enabled to add something almost daily to the existing stock of intelligence. The variety of unrecorded facts which continually strike the eye of an industrious experimenter, is indeed surprising.

The first business of a young chemist is to make himself acquainted with what is already known, with what has been already determined by the experiments of others. His next concern will be to learn something which no one else has yet discovered.

Chemistry is a science founded so entirely upon experiment that no person can understand it fully unless he personally performs such experiments as verify its fundamental truths. The hearing of lectures, and the reading of books, will never benefit him who attends to nothing else; for Chemistry can alone be studied to advantage *practically*. *One Experiment*, well conducted, and carefully observed by the student, from first to last, will afford more knowledge than the mere perusal of a whole volume.

DIFFERENT CLASSES OF EXPERIMENTS.—Chemical experiments may be divided, for convenience, into three sorts; namely, Determinative, Demonstrative, and Productive.

(*a.*) *Determinative Experiments* (Experiments of *Research*).—If anybody brings me a substance, and desires to know the nature of it, I must make a *determinative experiment;* in other words, I must submit it to analysis, or *determine* by *experiment*, what it is composed of.

Chemical analysis is of two sorts, qualitive and quantitive. A qualitive analysis makes known the chemical nature of the constituents of a compound, but not the relative quantities of those constituents. A quantitive analysis makes known both the nature of the constituents and the exact quantity of each by weight. Experiments of this sort are also called experiments of *research*. No man can execute an analysis without previously acquiring a considerable share of chemical information. Before a qualitive analysis can be executed, it is necessary to become acquainted with the properties of all the known elements and their principal compounds, as well as with the methods of determining whether any of them, on a certain occasion, are present or absent. The use of chemical *tests* or *re-agents*, depends upon the knowledge previously acquired, that particular bodies, in particular circumstances, act in a determinate manner. There is, for example, a liquid called oil of vitriol. I know that other liquids which contain certain substances in solution, upon being mixed with oil of vitriol, produce a precipitate. If, then, upon dissolving an unknown substance in water, and mixing the solution with oil of vitriol, I obtain no precipitate, I am certified that the substances alluded to are not present. It is evident, that unless I know beforehand what substances *do* give a precipitate with oil of vitriol, and what substances *do not*, it is useless to apply the test: because, whether I see a precipitate or not, I acquire no information. A vast number of other substances serve, as well as oil of vitriol, the office of chemical tests, and their employment in chemical analysis constitutes a very important part of chemical study. In the subsequent pages, the reader will frequently find it stated by what diversity of tests a particular substance may be known to be present, and also for what other substances any given compound is qualified to act as a test.

In quantitive analysis something more has to be done. Supposing a chemist to know how to detect all the ingredients of a compound, supposing that he has detected them, he has, in quantitive analysis, the additional task of separating these ingredients from one another, of freeing them from every possible intermixture, and of determining their respective weights. In some cases, two substances can be separated from each other with ease; in other cases, the separation cannot be effected without great difficulty. The methods of separation depend altogether upon the properties of the particular substances which are to be separated, and can only be learned by studying those properties. But success also depends upon the skill of the chemist in the performance of the numerous operations which occur in analysis. The fusions, solutions, filtrations, and evaporations, require to be performed with extreme care. If a drop of liquid falls down, or an atom of powder is blown away, the whole experiment is spoiled, and the labour, probably of weeks, is frustrated. To perform an analysis with accuracy should be the object of a student's ambition; but if he wishes to attain

that object, he must not only industriously study the properties of chemical bodies, but continually accustom himself to manipulation, that he may become dexterous in the performance of those operations upon which the success of an analysis mainly depends.

(*b.*) *Demonstrative Experiments* are of a different kind. They are employed in the *communication* of chemical knowledge. When a chemist has discovered anything new, he announces the discovery, and describes an experiment by which the truth of his statement can be proved. This is a demonstrative experiment. There are certain substances which, if heated at one end, very soon become hot at the other end; these are said to be *good conductors of heat.* There are other substances which, on being heated at one end, are a long time before they become hot at the other end; such substances are called *bad conductors of heat.* In general the metals are good conductors of heat, but the metal called platinum is a bad conductor of heat. The proof of this is easy. You take a short wire of platinum, hold it by the fingers at one end and place the other end in the flame of a spirit-lamp. You find that the heat comes to the fingers very slowly. This is a demonstrative experiment. As the students of a science must be supposed to be quite ignorant of its facts, it is the business of teachers to demonstrate the truth of their assertions by experiments, and accordingly lecturers on Chemistry commonly exhibit a great number of experiments. It would be in vain, however, to attempt, in a class, to demonstrate everything. Want of time forbids it. But a teacher should be careful not to state that as a chemical *fact*, which is *incapable of proof* by a chemical *experiment.*

(*c.*) *Productive Experiments.*—I have given this name to those experiments which have for object the *production* of chemical substances. The *Pharmacopœia* is a collection of productive experiments, containing instructions for preparing or producing the chemical substances employed in medicine. It will be understood, of course, that many analytical and demonstrative experiments are also productive experiments; but I understand by the latter term, those experiments only which are made for the express purpose of producing chemical preparations in quantities for use. Productive experiments on the small scale form an admirable exercise for young students. The preparation of the various acids, oxides, salts, sulphides, chlorides, iodides, &c., is capable of furnishing most useful information respecting the properties of those substances, and has the further beneficial effect of habituating the student to careful manipulation. A vast number of substances can be prepared in the small way with great facility, with the help of glass tubes, small flasks, capsules, glass plates, &c., in sufficient quantities to enable the operator to ascertain their properties and reactions with other substances. A student's spare time cannot be more agreeably or usefully occupied than in preparing and examining compounds not previously familiar to him.

Portions of substances so prepared may be preserved in small glass tubes closed with corks. Productive experiments in the large way are those which produce the metals, salts, acids, alcalies, and other commodities of the druggist, the drysalter, the colour-maker, &c.

MICRO-CHEMICAL EXPERIMENTS.—The chemical properties of a substance characterise equally the smallest portion of that substance, or the greatest mass. That which can be demonstrated with a pound, can often be demonstrated with a grain. Hence, chemical experiments may be performed, either with large portions of matter, or with small portions; and whether in any case a large or small portion should be operated upon, is a thing to be determined solely by expediency. In trade, where productive experiments are made with a view to obtain preparations for sale, the quantities operated upon are often extremely large, amounting to thousands of tons. In analysis, the quantity of a body submitted to a test weighs sometimes but the fraction of a grain. When a lecturer has to teach Chemistry to a large audience, he is obliged to make his demonstrative experiments upon a large scale, otherwise a majority of the persons present may not be able to perceive what takes place. And whenever a theory is built upon a single experiment, the lecturer should take particular care to make this experiment in such a manner that every person present may see and comprehend it fully; for if the demonstration is not made to *tell*, the theory sinks unheeded, and the arguments grounded upon it are worthless. I give this hint to the members of Mechanics' Institutions, who have lately adopted the useful practice of lecturing to one another.

As the demonstrative experiments of the lecture-room are unavoidably scanty and unsatisfactory, the student who desires to know somewhat more of the science than he can learn there, must necessarily pursue his studies in the laboratory, either at home or in public. It is indispensably necessary, that he perform with his own hands the fundamental experiments of chemistry, in the best manner that his time, his apparatus, and his means admit. He will find it of importance, in this case, to operate upon extremely small portions of matter; for he will then not only save time and money, but often be enabled to perform a successful experiment, when, by operating upon a large mass, he would as certainly fail. The preparation of the gases, the formation and crystallisation of salts, the application of tests, and a thousand other entertaining and instructive experiments, can all be performed by the student, better on a small scale than in the large way; nay more, a student in his closet very frequently succeeds in performing an experiment which fails on the lecture-table of the professor; because the hurry and business of a lecture-room, produce unavoidable accidents. This, therefore, is a circumstance of which the chemical student should be prepared to take every advantage. The faculty of experimenting with accuracy, facility, and economy, ought to be gained as speedily

as possible; for it is upon that faculty that the progress of the young chemist is principally dependent.

DIFFERENT SORTS OF CHEMICAL SUBSTANCES.—All natural bodies are either *simple* or *compound*. Those substances are SIMPLE, which cannot, by any known method, be separated, decomposed, or divided, in such a manner as to produce particles different in their properties from one another, or from the original substances. On the other hand, those substances are COMPOUND, which experiment is capable of resolving into particles of an unlike nature. For a period of many centuries, and even till a very late date, there were four substances held to be simple or elementary. These were fire, air, earth, and water. Of these four bodies, all others were supposed to be constituted, though nobody could ever prove, or indeed ever tried to prove, that this was the case. The system, however, continued to be orthodox until very lately, when three of these imaginary *elements*, namely, air, water, and earth, were proved to be compounds. But with respect to fire, it is still unknown whether it be simple or compound, or in what its essence consists, or by what causes its effects are produced. What the ancients considered to be simple bodies are no longer considered to be simple; but in place of these substances, the chemists of modern times have elevated to the dignity of elements a far more numerous race. No one, however, dogmatically asserts now-a-days that the substances termed elements are absolutely of a simple nature. The term element intimates no more than that the body to which it is applied, has never, in the opinion of modern chemists, been subjected to decomposition—that it has never been divided into particles different from one another, or from the original substance.

CHEMICAL ELEMENTS.—According to the present views of chemists, there are *sixty-one* ELEMENTS, or *simple substances;* that is to say, sixty-one substances which individually differ in properties from every other substance, and which, by their various combinations, produce the diversified compounds that constitute the material world,—animal, vegetable, and mineral. The names of these sixty-one elements are contained in the following list. I have added a few notes, to give the reader an idea of the relative importance and abundance of these elements, the state in which they exist in nature, and their classification into such as concern animal and vegetable substances, and such as do not. The properties of these elements, and the experiments which serve to separate them from other substances, and by which the separate identity of each is demonstrated, will be described in a subsequent part of this work.

1. OXYGEN.	3. NITROGEN.
2. HYDROGEN.	4. CARBON.

These four elements are of extreme importance, and exist in great abundance. Oxygen and hydrogen are the sole constituents of WATER.

Oxygen and nitrogen are the main constituents of ATMOSPHERIC AIR. Hydrogen and nitrogen constitute AMMONIA, which is formed in large quantities during the putrefaction and decomposition of animal and vegetable substances, ascends into the atmosphere, and, after thunder-storms, again falls to the earth, dissolved in rain. Oxygen and carbon constitute CARBONIC ACID, which always exists in atmospheric air. It is from these substances that VEGETABLES are derived. The ammonia and carbonic acid are carried down by rain-water into the *soil*, or pulverulent surface of the earth. The seeds and roots of plants decompose these compounds, and absorb their carbon, hydrogen, oxygen, and nitrogen; and the power of vegetation *organises* and converts them into new compounds, such as did not previously exist. These new vegetable substances consist for the greater part of carbon, hydrogen, and oxygen, and some of them of carbon, hydrogen, oxygen, and nitrogen. They serve afterwards as the food of ANIMALS, those which contain nitrogen being the most nutritious. The process of *digestion* converts the vegetable substances into animal substances, often with very slight change in chemical constitution, sometimes with none at all; the process of digestion in such cases consisting of a mere *solution* of the substances operated upon. When animals *die*, their component substances suffer decomposition, and reproduce their original constituents—water, ammonia, and carbonic acid—oxygen, hydrogen, nitrogen, and carbon. There is a constant circulation of the organic elements. Plants derive their means of nutriment from the air; animals from plants; and when the animals die, their components return to the atmosphere, to supply another generation of plants and of animals. These are mighty and wonderful transmutations, such as fill the mind with admiration and astonishment.

The various other compounds that are produced by the combination of these four elements with one another, are too numerous to be mentioned in this list. I will name only a few of them:—Oxygen, hydrogen, and nitrogen, produce liquid nitric acid. Oxygen, hydrogen, and carbon, produce oxalic acid, citric acid (lemon-juice), and vinegar. Hydrogen and carbon produce the gas that is employed in gas-lighting. Hydrogen, nitrogen, and carbon, produce prussic acid.

Carbon is found in nature pure in the diamond; nearly pure in graphite; and very abundantly in combination with hydrogen as coal.

5.—SILICON.

This element in combination with oxygen forms sand, flint, quartz, siliceous earth—and is one of the most abundant substances in nature. In combination with oxygen and potassium, forming silicate of potash, it enters into the constitution of straw (wheat-straw, cane, &c.)

6.—Aluminium.

In combination with oxygen this element forms clay, or aluminous earth. It also forms part of many minerals, sometimes combined only with oxygen, more frequently with the addition of silicon. Though so useful in promoting the growth of plants, it enters but rarely and in small proportion into their composition, and never forms a constituent of animal substances.

7.—Calcium.

In combination with oxygen, this element forms lime or calcareous earth. In combination with oxygen and carbon it forms chalk, marble, calcareous spar, and the numerous varieties of limestone. This element enters into the composition of many plants, and of certain parts of all animals, particularly their shells and bones.

The last three elements, in combination with oxygen, and mixed with one another, form the main portions of all the different kinds of *soils* and *rocks*, siliceous, aluminous, and calcareous. All other elements that occur in soils, exist in much smaller quantities than these, though some of them are yet more indispensable than they are, to promote the general growth, or the production of particular parts, of plants.

8.—Chlorine.—9. Sodium.

These two elements constitute the compound called sea salt or kitchen salt, a white substance used to season food, to preserve animal substances from putrefaction, and often also as a manure to promote the growth of plants. It is the chief saline matter of sea water, and it also exists in the state of a mineral.

The chlorine in combination with hydrogen forms muriatic acid, or spirits of salts; in combination with hydrogen and nitrogen it forms the salt called sal-ammoniac.

The sodium in combination with carbon and oxygen forms the detergent commonly called *soda*, or chemically, carbonate of soda. Sodium exists in a great number of plants, and chloride of sodium is found in many animal substances.

10.—Potassium.

This element is a constituent of the mineral felspar, and therefore one of the components of the granitic rocks, which form the great mass of the earth. It is indispensable for the growth of many plants. The wood of all trees contains it; and no tree can flourish in a soil which is without potassium. When wood is burnt, and the ashes washed, a salt is obtained which is termed potash, or pearl ash. This consists of potassium, oxygen, and carbon. The juice of the plant called *sorrel*,

contains a salt termed oxalate of potash. This consists of potassium, oxygen, and carbon, and hence this plant cannot grow in a soil which is free from potassium. The stems and leaves of the gramineæ contain silicate of potash, which consists of the elements silicon, oxygen, and potassium. In general, soils derive this element from the decomposition of felspar, or of other stones that contain it; but of late, it has been added artificially, by using as a manure the salt called nitrate of potash (saltpetre), which is a compound of oxygen, nitrogen, and potassium. This salt renders soils very fertile, because it adds to them two substances, both of which are highly beneficial to plants, namely, nitrogen and potassium.

11.—Sulphur (*Brimstone*).

In many parts of the world, as near Paris, in Derbyshire, &c., there are found large masses of a mineral called alabaster, gypsum, selenite, sulphate of lime, plaster of Paris, &c. This mineral consists of oxygen, calcium, and sulphur. The same substance is found dispersed in many soils, dissolved in most springs, rivers, and seas, and forming a limited part of many plants. Sulphur occurs in a free state near volcanoes, and in combination with many metals, in the ores termed pyrites. Thus, the very abundant golden-looking mineral called in Scotland slate diamonds, or iron pyrites, consists of sulphur in combination with iron. Sulphur combined with oxygen and hydrogen form the strong acid termed oil of vitriol, or sulphuric acid. It is a constituent, in small proportions, of many of those vegetable productions, which, in consequence of their containing nitrogen, afford nutritious food, namely, the substances called fibrin, albumen, casein, and gluten. It is very often present in small quantities in animal substances. It is a constituent of horn and of hair, and it is always present in eggs. The peculiar odour of rotten eggs is due to a compound containing sulphur and hydrogen.

12.—Phosphorus.

A few minerals are found that contain a considerable quantity of this element. Thus, phosphate of lead, found at Leadhills, contains oxygen, phosphorus, and lead. Apatite contains oxygen, calcium, chlorine, and phosphorus. In very many other minerals, a small proportion of this element occurs; so much so, that phosphorus occurs in most soils, and, in some state of combination, as phosphate of lime, phosphate of magnesia, &c., in many vegetables. From vegetables it passes into animals, of which probably none can live without phosphorus, since it not only exists in their liquid or soft parts, but is indispensable for the bones of the vertebrated animals, and the shells of the crustaceous. The earthy matter of bones consists chiefly of the elements phosphorus, calcium, and oxygen; and shells commonly contain the same elements, with the addition of carbon. This is the reason why ground bones and

shells form an excellent manure for soils. The odour of decaying fish is probably due to the presence of a compound containing phosphorus.

13.—Magnesium.

This element exists in abundance in the mineral called magnesian limestone, pretty largely in many rarer minerals, in small quantity in a great number of other minerals, and as a constant constituent of the saline matter of the ocean. From these sources it finds its way into most soils, thence, in small proportions, into many plants, and from them into animals. It is a constituent of blood and of bones. In the state of phosphate of magnesia and ammonia, it is found in the seeds of the gramineæ; and the potato contains a considerable quantity of phosphate of magnesia. It is an element, the knowledge of which is important to the agriculturist, as it appears to be often injurious to vegetation; yet, for the reason given above, it greatly promotes the growth of the potato plant. It is well known in medicine, for, in combination with oxygen and sulphur, it forms the bitter purgative substance called Epsom salt, or sulphate of magnesia, and, in combination with oxygen alone, the earth termed magnesia.

14.—Iron.

The most abundant and the most widely-diffused of all the metallic substances. It occurs in combination with oxygen as ochre, ironstone, &c.; with sulphur as pyrites; with carbon and oxygen as carbonate of iron, and this in combination with clay as clay-ironstone, a mineral of great abundance and importance in England and Scotland. It occurs, also, in many other forms of combination, too numerous to detail. It is the ordinary colouring matter of earths and soils. In minute quantities, it enters into all vegetables and animals. It is a constituent of the blood.

15.—Manganese.

This element, combined with oxygen, produces a black substance termed peroxide of manganese, a mineral which occurs in large quantities. Manganese forms many others minerals, and occurs in small quantities as the colouring matter of many more. It is found in plants in very small quantities, and but rarely in animals.

16.—Iodine.

Exists in sea-water, and enters into the composition of sea-weeds, sponges, &c.

17.—Fluorine.

Known chiefly as a component of the mineral called Fluorspar, in which it is combined with calcium. It occurs in some other minerals, and has been found in the bones of animals.

The foregoing elements all enter into the composition of plants, and most of them into the composition of animals. In contradistinction to the *organic* elements, namely, the four elements, oxygen, hydrogen, carbon, and nitrogen, the others, from No. 5 to No. 17, are termed the *inorganic*, or mineral constituents of plants. These inorganic elements occur in plants in very small proportions relatively to the proportions of the organic elements; yet they are not less essential than the latter to the development and growth of the plants, so much so, that soils in which particular mineral constituents do not exist, are absolutely sterile in regard to the vegetation of plants which require these particular constituents, notwithstanding the presence of any excess of organic manure.

The following elements belong exclusively to inorganic nature. They form no part of plants or animals, nor are they useful in promoting the growth of either class of organized bodies.

18. Gold.
19. Silver.
20. Copper.
21. Lead.
22. Tin.
23. Zinc.
24. Mercury.
25. Antimony.
26. Arsenic.
27. Platinum.

Well-known common metals, which occur in pretty considerable quantities.

28. Bismuth.
29. Cobalt.
30. Nickel.
31. Chromium.
32. Palladium.
33. Cadmium.
34. Molybdenum.
35. Uranium.
36. Vanadium.
37. Tungsten.
38. Tellurium.
39. Pelopium.
40. Niobium.
41. Tantalium.
42. Titanium.
43. Osmium.
44. Rhodium.
45. Iridium.
46. Ruthenium.

Metals,—rarer, less known, and less used than the foregoing. Those which are most abundant and most used are the first seven in the list.

47. Cerium.
48. Terbium.
49. Erbium.
50. Didymium.
51. Lantanium.
52. Thorium.
53. Zirconium.
54. Yttrium.
55. Glucinum.

Metallic bases of rare earths, seldom separated from their ores, and when separated applied to no use.

56. Strontium.
57. Barium.
58. Lithium.

Metallic bases of alcaline earths. Barium occurs plentifully in the mineral called Heavy Spar. It is chiefly used in chemical experiments. Lithium is extremely rare.

59. Boron. The base of the boracic acid.
60. Selenium. Rare: resembles sulphur in many of its properties.
61. Bromine. Resembles chlorine in many of its properties. Is employed in the arts to a certain extent. Occurs in sea-water, and in some salt springs.

THE CAUSE OF CHEMICAL COMBINATION.—When the elementary bodies are placed in contact under particular circumstances, they unite or combine together, and produce compound bodies. Some combinations are effected very readily, and some with great difficulty, and there are certain elements which can scarcely by any means be made to combine. The compounds produced by the combination of the elements, possess properties very different from those of the elements of which they are composed. The POWER, in virtue of which simple bodies can combine and produce compounds, is one of which the nature is totally unknown to man. Chemists have learned no more than that simple bodies, or bodies supposed to be simple, DO COMBINE; but WHY *they combine*, or *what it is* which MAKES THEM *combine*, they have not discovered.

It is sometimes stated that certain bodies combine with one another, because they have an *affinity* for one another, and that these bodies which do not combine together have no affinity for each other; and it is thence argued that *chemical affinity* is the *cause* of combination.

Now, it is convenient to have a *term* to denote that kind of attraction which binds together the elements of a chemical compound, as distinguished from that physical attraction which makes the particles of all bodies cohere. Using the word *cohesion* to denote this latter quality, we may use the word *affinity* to signify the former. But we must bear in mind, that by so doing, we merely give a *name* to a phenomenon, not an *explanation* of it.

VARIETIES OF COMPOUNDS.—*Acids, Bases, Salts, &c.* The Chemical Elements are classed into two groups, the METALS and the METALLOIDS. The line of demarcation is not very distinct, but the following elements are commonly called metalloids:—

1. Oxygen.	7. Chlorine.	13. Silicon.
2. Hydrogen.	8. Bromine.	To which some
3. Nitrogen.	9. Iodine.	chemists add
4. Sulphur.	10. Fluorine.	14. Arsenic.
5. Selenium.	11. Carbon.	15. Tellurium.
6. Phosphorus.	12. Boron.	

The residue of the elements belong to the group of metals.

Oxygen, in combining with another element, produces an *oxide*. When this combination occurs with a metalloid, the compound is an *acid;* when it occurs with a metal, it is commonly a *base;* and the acids and bases thus produced combine with one another to form *salts*. Thus the salt called sulphate of soda, is held by the prevalent theory of chemistry to contain sulphuric acid and soda. The sulphuric acid is composed of oxygen and sulphur (a metalloid), and the soda of oxygen and sodium (a metal).

There is, however, another class of salts, which are produced by direct

combination between the metals and some of the metalloids, without the incorporation of oxygen. Thus, kitchen salt is a compound of chlorine and sodium; fluorspar is a compound of calcium and chlorine; and iron pyrites is a compound of iron and sulphur. The chemical names of these compounds are chloride of sodium, fluoride of calcium, and sulphide of iron.

The compounds produced by hydrogen are very variable in their characters: with oxygen it forms the mild compound we call water; with chlorine it forms muriatic acid; with nitrogen it forms the alcali ammonia; with oxygen and metalloids together it produces strong acids, as nitric acid and sulphuric acid; with oxygen and metals together it produces alcalies, as caustic potash, caustic soda, and slaked lime. These explanations are given in a general sense. There are many exceptions to these rules. It is impossible to describe in a few sentences the diversified actions of the chemical elements.

THE CAUSE OF CHEMICAL DECOMPOSITION.—When chemical compounds are strongly electrified, they suffer decomposition, and the liberated atoms of their constituents appear, partly at the positive pole, and partly at the negative pole, of the electric apparatus. Those which appear at the positive pole are denominated *electro-negative* elements, and those which appear at the other pole, *electro-positive* elements. It is found that every element is *negative* towards a portion of the elements, and *positive* towards the rest.

The manifestation of electrical appearances at the moment when an act of combination or decomposition is effected, throws no light upon the nature of the force which makes the elements combine. We see nothing more than the phenomena by which the acts of combination and decomposition are attended.

When a number of chemical elements are set at liberty in juxtaposition, those combinations take place, which produce such compounds as can best exist *under the circumstances* in which the occurrence is brought to pass. The same elements brought together at a *low* temperature, at a *medium* temperature, and at a *high* temperature, produce different compounds, *i. e.*, they produce such compounds as can best exist *under the circumstances* of the trial.

If a compound, consisting of a powerful electro-negative element and of an indifferent element, *i. e.*, of one possessing no very marked electrical powers, be brought into contact with a powerful electro-positive element, decomposition is immediately effected, and those two elements which exhibit the antagonistic electricities most strikingly, combine, to the exclusion of the other. The VERY NEUTRAL compound produced by the combination of an *electro-positive* with an *electro-negative* element, can better exist in presence of an *indifferent* element, than the SEMI-NEUTRAL compound composed of an *indifferent* in combination with an *electro-negative*, can exist in presence of an *electro-positive*. In the one

case, the electrical power is partially at rest; in the other, its dispersive influence is in full operation.

When compounds are placed in juxtaposition, in a state fitted for chemical action, as, for example, in solution in water, they are observed to *decompose each other*, PROVIDED that, by doing so, they can give origin to other compounds, more capable than the original compounds of emerging from the sphere of each other's action; OTHERWISE, they *do not decompose each other*. If, for example, we put together two soluble salts, of such a nature as to give rise, by an interchange of their antagonistic electrical elements, that is to say, of their *acids* and *bases*, to two other salts of the same degree of solubility, then no decomposition takes place. But if, on the other hand, we place together two salts of such a nature, that the interchange of their antagonistic electrical elements can produce a salt of less solubility than the original salts, then decomposition is effected,—let the insolubility of the new salt result from its tendency to assume either the solid form or the gaseous.

Hence we draw a rule useful in practice:—*Two saline compounds in solution being given, if the base of the one can produce, with the acid of the other, a compound insoluble in the water of the given solutions, then, upon mixing the solutions, precipitation will occur.*

For example, the compound called sulphate of barytes is insoluble in aqueous solutions of the sulphates and chlorides. If, therefore, we mix a solution of *chloride of barium* with a solution of *sulphate of soda*, the sulphur and oxygen of the latter combine with the barium of the former, and precipitate in the state of *sulphate of barytes*—leaving *chloride of sodium* in the supernatant solution.

A mixture of borate of soda and sulphuric acid produces, *at a red heat*, borate of soda and sulphuric acid; but at the *heat of boiling water* and in solution it produces sulphate of soda and boracic acid. In the first case, the sulphuric acid separates by volatilization; in the second case, the boracic acid separates by precipitation. Thus the proximate constituents afforded by the decomposition of compounds are different under different circumstances of decomposition. If the two original compounds, and the two compounds capable of being produced by the interchange of their antagonistic electric elements, were all equally fixed in the fire, and equally soluble in water, there would be no decomposition.

Vain, therefore, is the attempt to effect double decomposition, excepting where it can produce new compounds, self-empowered to get readily out of each other's vicinity; but when this is provided for, decompositions are readily and constantly effected. Whenever we desire to know, whether or not there will be a precipitate produced when two given saline solutions are mixed together, we do not require to look at what have been termed *tables of affinity*, we only need to examine whether the two given soluble salts can by exchanging their acids and bases, produce an insoluble salt. If they can, then there will

certainly be a precipitate produced when the solutions are mixed together. In point of fact, most tables of affinity are merely tables of precipitation, and are founded on the assumption that the degrees of insolubility of different substances, mark the strength of the affinity of their components.

ATOMIC WEIGHTS OF THE ELEMENTS.

Aluminum	Al.	170,900	Molybdenum	Mo.	574,829
Antimony	Sb.	806,452	Nickel	Ni.	369,330
Arsenic	As.	468,750	Niobium	Nb.	——
Barium	Ba.	856,770	Nitrogen	N.	87,530
Bismuth	Bi.	1299,975	Norium?		——
Boron	B.	136,204	Osmium	Os.	1242,624
Bromine	Br.	499,810	Oxygen	O.	100,000
Cadmium	Cd.	696,767	Palladium	Pd.	665,477
Calcium	Ca.	251,651	Pelopium	Pe.	——
Carbon	C.	75,000	Phosphorus	P.	196,020
Cerium	Ce.	590,800	Platinum	Pt.	1232,080
Chlorine	Cl.	221,640	Potassium	K.	489,300
Chromium	Cr.	335,091	Rhodium	Rh.	651,962
Cobalt	Co.	368,650	Ruthenium	Ru.	651,962
Copper	Cu.	395,600	Selenium	Se.	495,285
Donarium?		——	Silicon	Si.	277,778
Didymium	D.	620,000	Silver	Ag.	1349,660
Erbium	E.	——	Sodium	Na.	289,729
Fluorine	F.	117,717	Strontium	Sr.	545,929
Glucinum	Be.	87,124	Sulphur	S.	200,750
Gold	Au.	1229,165	Tantalium	Ta.	——
Hydrogen	H.	6,250	Tellurium	Te.	801,760
Ilmenium?	Il.	——	Terbium	Tb.	——
Iodine	I.	792,996	Thorium	Th.	743,860
Iridium	Ir.	1232,080	Tin	Sn.	735,294
Iron	Fe.	350,527	Titanium	Ti.	301,550
Lantanium	La.	588,000	Tungsten	W.	1150,780
Lead	Pb.	1294,645	Vanadium	V.	856,892
Lithium	L.	81,660	Uranium	U.	742,875
Magnesium	Mg.	150,190	Yttrium	Y.	——
Manganese	Mn.	344,684	Zinc	Zn.	406,591
Mercury	Hg.	1251,290	Zirconium	Zr.	419,728

THE ATOMIC THEORY.

THE elements of which all compounds are composed are supposed to exist in the state of extremely small, solid, indivisible particles, which are called ATOMS.

These atoms are supposed to differ in their relative weights. Thus, for example, it is imagined that if we could separate from the mass a single atom of CARBON and a single atom of OXYGEN, and weigh them one against the other, their relative weights would be found to be in the relation of Carbon 3 to Oxygen 4.

It is impossible to make such an experiment, because the atoms of the elements—if any such small solid atoms really exist—are too small to be individually perceptible. The relative weights of the atoms have therefore been fixed by experiments of another kind, or by arguments depending upon circumstantial evidence, which it would not be convenient to discuss here. I shall confine myself to practical considerations, and simply give a table which contains the atomic weights of the elements, as agreed upon by modern chemists, after numberless researches of the description to which I have alluded. The numbers I use in this table are those of BERZELIUS, as given in the last edition of ROSE'S "*Ausführliches Handbuch des analytischen Chemie*," Berlin, 1852.

The Table is given in the opposite page.

Against each name in the table a symbol is placed, which consists of one or more letters, and which in all cases signifies *an atom* of the element it refers to. Thus

O. signifies 100,000 parts of oxygen.
Cu. signifies 395,600 parts of copper.

When the elements combine to form compounds, they combine in *atomic quantities;* that is to say, one or more atoms of one element combines with one or more atoms of another element to form a compound; and the weight of the compound is equal to the sum of the weights of the elements which compose it. Thus O combines with HH to produce O+HH. That is to say, 100,000 parts of oxygen combine with twice 6,250 (or two atoms) = 12,500 parts of hydrogen, to produce 112,500 parts of WATER, which compound is composed of the elements oxygen and hydrogen in these proportions.

In like manner we account for the composition of all sorts of compounds, all of which are built up of the atoms of the elements, and all

of which have the same weight as the sum of the weights of the several atoms of which they are composed.

TABLE OF THE ATOMIC WEIGHTS OF CHEMICAL COMPOUNDS.

In the following table (page 22) is presented the atomic weights of many important chemical compounds, with the arrangement of symbols by which their presumed composition is indicated. Thus, for example, the compound called SULPHATE of LEAD, is denoted by PbO,SO^3. This gives an expression of the prevailing *theoretical opinion*, that in sulphate of lead we have one atom of oxygen combined with one atom of lead, forming one atom of oxide of lead, and three atoms of oxygen combined with one atom of sulphur, forming one atom of sulphuric acid, and that these two primary compounds—the acid formed by oxygen with the metalloid and the base formed by oxygen with the metal—are combined together to form a secondary compound, or salt.

It is evident that this compound contains the three elements, lead, sulphur, and oxygen; these form what are called the *ultimate* elements of the compound. But it is by no means *certain* that these elements are combined into what are called the *proximate* elements, in the manner which is represented by the symbol. It is true that the elements *may be* combined together as they are represented by the formula PbO,SO^3; but it is also true, that the combination *may be* Pb,SO^4, or PbS,O^4, or PO^2,SO^3, &c.

I cannot enter here into a discussion of this difficult matter,—suffice it for the present purpose to say, that the symbols represent the composition of the compounds that are named in the table, according to the most prevalent views of modern chemists, and in such a manner that the numbers may be used in all experimental operations with as much certainty of success, as if the theoretical views regarding the proximate constitution of the compounds, were proved to be absolutely true.

I add a description of one of the longer symbols, to explain the manner in which the *letters* and *numbers* are combined. I take for the example, green copperas, *the crystallised sulphate of the protoxide of iron*, the symbol or formula for which salt is

$$FeO,SO^3+7H^2O.$$

The theoretical or proximate constitution of this salt is stated by this formula to be as follows:—One atom of protoxide of iron (FeO), is combined with one atom of sulphuric acid (SO^3), and this compound is combined with seven atoms of water of crystallisation ($7H^2O$). The comma (,) placed between FeO and SO^3 marks the separation between the two proximate constituents. The sign *plus* (+) separates another proximate constituent, and more effectively than the comma would separate it. It signifies that the water is less strongly

combined with the salt, than the acid and the base of the salt are combined with one another. The superior figure (²) which follows the symbol of the acid multiplies only the symbol or letter which immediately goes before it, namely the O. The large figure (7) multiplies all the letters and numbers that follow it, till you come to another comma (,) or to the sign plus (+) or to a full point.

In making experiments with chemical substances, those proportions are to be taken which are stated in the table. Thus, 664¾ parts of anhydrous carbonate of soda, or 1789¾ parts of crystallised carbonate of soda, must be taken to produce 2015½ parts of crystallised sulphate of soda, or 733 parts of chloride of sodium, and the quantity of the acids required to obtain these results are 613½ parts of hydrate of sulphuric acid, or 455¾ parts of muriatic acid gas, or as much liquid muriatic acid as contains that quantity of muriatic acid gas. All these quantities are stated *by weight*.

Such experiments as these can be very conveniently represented by means of symbols put into the form of mathematical equations. Thus:—

$$NaO,CO^2 + 10\,H^2O + H^2Cl^2 = NaCl^2 + CO^2 + 11\,HO.$$

$$NaO,CO^2 + H^2O,SO^3 + 9\,H^2O = NaO,SO^3 + 10\,H^2O + CO^2.$$

In both these cases, the carbonic acid is expelled in the gaseous state. The water that exists in the crystallised carbonate of soda is lost in the solution. The water required by the crystals of sulphate of soda is gained from the solution.

These weights are of course all *relative* to one another. What *absolute quantities* of substances are to be used in any operation, depends upon the *object* for which the operation is performed. An atomic weight of any substance may be weighed out in grains, pounds, tons, or quantities of any other denomination.

In another section of this work, where I describe the preparation of Equivalent Test Liquors, it is recommended, that when the *Atomic Weight* of any substance is taken in *English grains*, it shall be called a TEST ATOM. By this means the *relative* quantities represented by the atomic weights, are, for specific experimental purposes, converted into *absolute* quantities.

ATOMIC WEIGHTS.

Acetic Acid, *anhydrous* . .	$C^4H^6O^3$	637.5
— —, *hydrate*	$C^4H^6O^3+Aq^1$	750.
Alcohol, ...	C^2H^6O	287.5
Alumina, ...	Al^2O^3	641.8
— Sulphate, ...	$Al^2O^3,3SO^3$	2144.1
Aluminum, ...	Al	170.9
— *two atoms*, ...	Al^2	341.8
Alum, Potash, *cryst.*. . .	$KO,SO^3+Al^2O^3,3SO^3+Aq^{24}$	5934.1
— Ammonia, *cryst.* .	$N^2H^8O,SO^3+Al^2O^3,3SO^3+Aq^{24}$	5669.9
Ammonia, ...	N^2H^6	212.6
— Sesquicarbonate, . . .	$2N^2H^8O,3CO^2$	1475.1
— Bicarbonate, ...	$N^2H^8O,H^2O,2CO^2$	987.5
— Molybdate, ...	N^2H^8O,MoO^3	1199.9
— Nitrate, ...	N^2H^8O,N^2O^5	1000.2
— Oxalate, ...	N^2H^8O,C^2O^3	775.1
— Sulphate, ...	N^2H^8O,SO^3	825.8
Ammonium, ...	N^2H^8	225.1
— Oxide, ...	N^2H^8O	325.1
— Chloride, ...	$N^2H^8Cl^2$	668.3
— Iodide, ...	$N^2H^8I^2$	1811.1
— Sulphide, ...	N^2H^8S	425.9
Antimony, ...	Sb	806.5
— *two atoms*, ...	Sb^2	1612.9
— Antimonious Acid, . . .	Sb^2O^3	1912.9
— Antimonic Acid, . . .	Sb^2O^5	2112.9
— Sulphide, ...	Sb^2S^3	2215.2
Antimony and Potash, Tartrate,	$KO,Sb^2O^3+2(C^4H^4O^5)+H^2O$	4264.7
Antimoniuretted Hydrogen, .	H^6Sb^2	1650.4
Arsenic, ...	As	468.8
— *two atoms*, ...	As^2	937.5
— Arsenious Acid, . . .	As^2O^3	1237.5
— Arsenic Acid, . . .	As^2O^5	1437.5
— Sulphide, *Realgar*, . .	As^2S^2	1339.0
— — *Orpiment*, ...	As^2S^3	1539.8
— Pentasulphide, . . .	A^2S^5	1941.3
Arseniuretted Hydrogen, . .	H^6As^2	975.
Barium, ...	Ba	856.8
— Peroxide, ...	BaO^2	1056.8
— Chloride, *anhydrous*, . .	$BaCl^2$	1300.1
— — *cryst.*, ...	$BaCl^2+Aq^2$	1525.1

Barium, Silico-Fluoride, . .	$3BaF^2+2SiF^6$	5244.6
— Sulphide, ...	BaS	1057.6
Barytes, ...	BaO	956.8
— Hydrate, ...	BaO,Aq	1069.3
— Acetate, *cryst.*, . . .	$BaO,C^4H^6O^3+3Aq$	1931.8
— Carbonate, ...	BaO,CO^2	1231.8
— Chromate, ...	BaO,CrO^3	1591.9
— Nitrate, ...	BaO,N^2O^5	1631.8
— Oxalate, ...	$BaO,C^2O^3+H^2O$	1519.3
— Phosphate, ...	$2BaO,P^2O^5$	2805.6
— Sulphate, ...	BaO,SO^3	1457.5
Bismuth, ...	Bi	1300.
— Nitrate, ...	$Bi^2O^3,N^2O^5+9H^2O$	4587.5
— Oxide, ...	Bi^2O^3	2900.
Bismuthic Acid, ...	Bi^2O^5	3100.
Boracic Acid, ...	BO^3	436.2
— — *cryst.*, ...	BO^3+Aq^3	773.7
Boron, ...	B	136.2
— Chloride, ...	BCl^6	1466.1
— Fluoride, ...	BF^6	842.4
Bromic Acid, ...	Br^2O^5	1499.6
Bromine, ...	Br	499.8
— *two atoms*, ...	Br^2	999.6
Cadmium, ...	Cd	696.8
— Oxide, ...	CdO	796.8
— Bromide, ...	$CdBr^2$	1696.4
— — *cryst.*, ...	$CdBr^2+4H^2O$	2146.4
— Bromate, *cryst.*, . . .	$CdO,Br^2O^5+H^2O$	2408.9
— Sulphate, *cryst.*, . . .	CdO,SO^3+4H^2O	1747.5
— Sulphide, ...	CdS	897.6
Calcium, ...	Ca	251.7
— Chloride, ...	$CaCl^2$	694.9
— — *cryst.*, ...	$CaCl^2+Aq^6$	1369.9
— Fluoride, ...	CaF^2	487.1
— Sulphide, ...	CaS	452.4
Carbon, ...	C	75.
— *two atoms*, ...	C^2	150.
Carbonic Acid, ...	CO^2	275.
— *two atoms*, ...	$2CO^2$	550.
— Oxide, ...	CO	175.
Carbon, Sulphuret, . . .	CS^2	476.5
Cerium, ...	Ce	590.8
Chlorine, ...	Cl	221.6
— *two atoms*, ...	Cl^2	443.3
Chloric Acid, ...	Cl^2O^5	943.3

Chromium,	Cr	335.1
— Sesquioxide,	Cr^2O^3	970.2
— Oxychloride,	CrO^2Cl^2	978.4
Chromic Acid,	CrO^3	635.1
Citric Acid, *hypothetical*, 3 basic	$C^{12}H^{10}O^{11}$	2062.5
— *hydrate*, —	$3H^2O,C^{12}H^{10}O^{11}$	2400.
— *commercial crystals*, —	$3H^2O,C^{12}H^{10}O^{11}+Aq^2$	2625.
Cobalt,	Co	368.7
— Oxide,	CoO	468.7
— Sesquioxide,	Co^2O^3	1037.3
— Sulphate, *cryst.*,	CoO,SO^3+7H^2O	1756.9
Copper,	Cu	395.6
— Red Oxide,	Cu^2O	891.2
— Black Oxide,	CuO	495.6
— Acetate, *cryst.*,	$CuO,C^4H^6O^3+Aq$	1245.6
— Protochloride,	Cu^2Cl^2	1234.5
— Perchloride,	$CuCl^2$	838.9
— Nitrate, *cryst.*,	$CuO,N^2O^5+Aq^6$	1845.7
— Sulphate,	CuO,SO^3	996.4
— — *cryst.*,	CuO,SO^3+Aq^5	1558.9
— Subsulphide,	Cu^2S	992.
— Sulphide,	CuS	596.4
Cyanogen,	$N^2C^2=Cy^2$	325.1
— Sulphide,	Cy^2S^2	726.6
Didymium,	D	620.
Donarium,		
Erbium,	E	
Ether,	$C^4H^{10}O$	462.5
Formic Acid, *hydrate*,	$H^2O,C^2H^2O^3$	575.
Fluorine,	F	117.7
— *two atoms*,	F^2	235.4
Glucinum,	Be	87.1
Glucina,	Be^2O^3	474.2
Gold,	Au	1229.2
— *two atoms*,	Au^2	2458.3
— Chloride,	Au^2Cl^6	3788.2
Hydriodic Acid,	H^2I^2	1598.5
Hydrobromic Acid,	H^2Br^2	1012.5
Hydrochloric Acid,	H^2Cl^2	455.8
Hydrocyanic Acid,	$H^2+N^2C^2$	337.6
Hydrofluoric Acid,	H^2F^2	247.9
Hydrofluosilicic Acid,	$3H^2F^2+2SiF^6$	2711.7
Hydrogen,	H	6.25
— *two atoms*,	H^2	12.5
— Peroxide,	H^2O^2	212.5

Hydrosulphuric Acid,	H^2S	213.5
Ilmenium,	Il	
Iodic Acid,	I^2O^5	2086.
Iodine,	I	793.
— *two atoms*,	I^2	1586.
— Bromide,	I^2Br^{10}	6584.1
— Chloride,	I^2Cl^{10}	3802.4
Iridium,	Ir	1232.1
Iron,	Fe	350.5
— *two atoms*,	Fe^2	701.1
— Protoxide,	FeO	450.5
— Peroxide,	Fe^2O^3	1001.1
— Ferric Acid,	FeO^3	650.5
— Carbonate,	FeO,CO^2	725.5
— Protochloride,	$FeCl^2$	793.8
— Perchloride,	Fe^2Cl^6	2031.
— Protosulphate,	FeO,SO^3	951.3
— — *cryst.*,	FeO,SO^3+7H^2O	1738.8
— Sulphide,	FeS	551.3
— Bisulphide,	FeS^2	752.1
Lantanium,	La	588.
Lead,	Pb	1294.6
— Brown Oxide,	PbO^2	1494.6
— Orange Oxide,	Pb^2O^3	2889.2
— Red Oxide,	Pb^3O^4	4283.8
— Yellow Oxide,	PbO	1394.6
— Acetate, *cryst.*,	$PbO,C^4H^6O^3+3H^2O$	2369.6
— —	$PbO,C^4H^6O^3$	2032.1
— Carbonate,	PbO,CO^2	1669.6
— Chloride,	$PbCl^2$	1737.9
— Chromate,	PbO,CrO^3	2029.7
— Fluoride	PbF^2	1530.
— Iodide,	PbI^2	2880.6
— Nitrate,	PbO,N^2O^5	2069.7
— Oxalate,	PbO,C^2O^3	1844.6
— Phosphate,	$2PbO,P^2O^5$	3681.2
— Sulphate,	PbO,SO^3	1895.4
— Sulphide,	PbS	1495.4
Lime, Anhydrous,	CaO	351.7
— Hydrate,	CaO,H^2O	464.2
— Acetate, *anhyd.*,	$CaO,C^4H^6O^3$	989.2
— Carbonate,	CaO,CO^2	626.7
— Citrate, *precipitated*,	$3CaO,C^{12}H^{10}O^{11}+Aq$	3230.1
— Nitrate,	CaO,N^2O^5	1026.8
— — *cryst.*,	$CaO,N^2O^5+Aq^4$	1476.8

Lime, Oxalate,	CaO,C^2O^3	801.7
— —	$CaO,C^2O^3+H^2O$	914.2
— —	$CaO,C^2O^3+2H^2O$	1026.7
— Phosphate,	$2CaO,P^2O^5$	1595.3
— —	$2CaO,P^2O^5+4H^2O$	2045.3
— Sulphate,	CaO,SO^3	852.4
— — *cryst.*,	CaO,SO^3+2H^2O	1077.4
— Tartrate,	$CaO,C^4H^4O^5+4H^2O$	1626.7
Lithia,	LO	181.7
Lithium,	L	81.7
Magnesia,	MgO	250·2
— Carbonate,	MgO,CO^2,H^2O	637.7
— Phosphate,	$2MgO,P^2O^5$	1392.2
— Sulphate,	MgO,SO^3	750.9
— — *cryst.*,	MgO,SO^3+7H^2O	1538.4
Magnesium,	Mg	150.2
— Chloride,	$MgCl^2$	593.5
Manganese,	Mn	344.7
— Peroxide,	MnO^2	544.7
— Protoxide,	MnO	444.7
— Deutoxide	Mn^2O^3	989.4
— Red Oxide,	Mn^3O^4	1434.1
— Chloride,	$MnCl^2$	789.
— Sulphate,	MnO,SO^3	945.4
— — *cryst.*,	MnO,SO^3+Aq^7	1732.9
Manganic Acid,	MnO^3	644.7
Hypermanganic Acid,	Mn^2O^7	1389.4
Marsh Gas,	H^4C	100.
Mercury,	Hg	1251.3
— *two atoms*,	Hg^2	2502.6
— Protoxide,	Hg^2O	2602.6
— Peroxide,	HgO	1351.3
— Perchloride, (*Sublimate*,)	$HgCl^2$	1694.6
— Protochloride, (*Calomel*,)	Hg^2Cl^2	2945.9
— Protochromate,	Hg^2O,CrO^3	3237.7
— Cyanide,	$HgCy^2$	1576.4
— Iodide,	HgI^2	2837.3
— Protonitrate,	$Hg^2O,N^2O^5+Aq^2$	3502.6
— Pernitrate,	$2HgO,N^2O^5+Aq^2$	3602.6
— —	$3HgO,N^2O^5+Aq$	4841.4
— Persulphate,	HgO,SO^3	1852.
— Protosulphate,	Hg^2O,SO^3	3103.3
— Sulphide,	Hg^2S	2703.3
— —	HgS	1452.
Molybdenum	Mo	574.8

Molybdic Acid, ...	MoO^3	874.8
Muriatic Acid, ...	H^2Cl^2	455.8
Nickel, ...	Ni	369.3
— Oxide, ...	NiO	469.3
— Sesquioxide, ...	Ni^2O^3	1038.7
— Sulphate, *cryst.*, . . .	NiO,SO^3+7H^2O	1757.6
Niobium, ...	Nb	
Niobic Acid, ...	Nb^2O^3	
Nitric Acid	N^2O^5	675.1
— *hydrate*, ...	N^2O^5+Aq	787.6
Nitrous Acid, ...	N^2O^3	475.1
Nitric Oxide, ...	NO	187.5
— *two atoms*, ...	N^2O^2	375.1
Nitrous Oxide, ...	N^2O	275.1
Nitrogen, ...	N	87.5
— *two atoms*, ...	N^2	175.1
Norium, ...		
Olefiant Gas, ...	CH^2	87.5
Osmium, ...	Os	1242.6
Osmic Acid, ...	OsO^4	1642.6
Oxalic Acid, *anhydrous*, . .	C^2O^3	450.
— — *effloresced*, . .	C^2O^3+Aq	562.5
— — *cryst.*, . . .	$C^2O^3+Aq^3$	787.5
Oxygen, ...	O	100.
Palladium, ...	Pa	665.5
Pelopic Acid, ...	Pe^2O^3	
Pelopium, ...	Pe	
Perchloric Acid	Cl^2O^7	1143.3
Phosgen Gas, ...	$CO+Cl^2$	618.3
Phosphorus, ...	P	196.
— *two atoms*, ...	P^2	392.
Phosphoric Acid, . . .	P^2O^5	892.
Phosphorous Acid, . . .	P^2O^3	692.
Phosphuretted Hydrogen, .	H^6P^2	429.5
Platinum, ...	Pt	1232.1
— Chloride, ...	$PtCl^4$	2118.7
— Ammonium Chloride, .	$N^2H^8Cl^2+PtCl^4$	2787.1
— Potassium Chloride, . .	KCl^2+PtCl^4	3051.3
Potash, Anhydrous, . . .	KO	589.3
— Hydrate, ...	KO,H^2O	701.8
— Antimoniate, ...	KO,Sb^2O^5	2702.2
— Arseniate, ...	$2KO,As^2O^5$	2616.1
— — Acid, ...	$KO,As^2O^5+Aq^2$	2251.8
— Carbonate, ...	KO,CO^2	864.3
— Bicarbonate, *cryst.*, . .	$KO,H^2O,2CO^2$	1251.8

Potash, Chlorate, . . .	KO,Cl^2O^5	1532.6
— Perchlorate, ...	KO,Cl^2O^7	1732.6
— Chromate, Red, . . .	$KO,2CrO^3$	1859.5
— — Yellow, ...	KO,CrO^3	1224.4
— Manganate, ...	KO,MnO^3	1234.
— Permanganate, . . .	KO,Mn^2O^7	1978.7
— Nitrate, ...	KO,N^2O^5	1264.4
— Oxalate, ...	$KO,C^2O^3+H^2O$	1151.8
— Binoxalate	$KO,2C^2O^3+3H^2O$	1826.8
— Quadroxalate, . . .	$KO,4C^2O^3+3H^2O$	3176.8
— Prussiate, Red, . . .	$3KCy^2,Fe^2Cy^6$	4119.3
— — Yellow, . . .	$2KCy^2,FeCy^2$	2304.3
— — — *cryst.*, . . .	$2KCy^2,FeCy^2+3H^2O$	2641.8
— Sulphate, ...	KO,SO^3	1090.1
— Bisulphate, ...	KO,SO^3+H^2O,SO^3	1703.3
— Tartrate, ...	$KO,C^4H^4O^5$	1414.3
— Bitartrate, ...	$KO,2(C^4H^4O^5)+H^2O$	2351.8
Potassium, ...	K	489.3
— Protoxide (Potash), . .	KO	589·3
— Peroxide, ...	KO^2	789.3
— Bromide, ...	KBr^2	1488.9
— Chloride, ...	KCl^2	932.6
— and Platinum Chloride, .	KCl^2+PtCl^4	3051.3
— Cyanide, ...	KCy^2	814.4
— Sulpho-cyanide, . . .	KCy^2S^2	1215.9
— Fluoride, ...	KF^2	724.7
— Fluo-Silicide, . . .	$3KF^2+2SiF^6$	4142.1
— Iodide, ...	KI^2	2075.8
— Sulphide, ...	KS	690.1
— Pentasulphide, . . .	KS^5	1493.1
Prussic Acid, ...	H^2Cy^2	337.6
Pyrogallic Acid, *sublimed*, .	$C^6H^3O^4$	1050.
Rhodium, ...	Rh	652.
Ruthenium, ...	Ru	652.
Selenium, ...	Se	495·3
Selenic Acid, ...	SeO^3	795·3
Selenious Acid, ...	SeO^2	695·3
Silica (Silicic Acid), . .	SiO^3	577·8
Silicon, ...	Si	277.8
— Chloride, ...	$SiCl^6$	1607.6
— Fluoride, ...	SiF^6	984.
Silver, ...	Ag	1349.7
— Oxide, ...	AgO	1449.7
— Bromide, ...	$AgBr^2$	2349.3
— Chloride, ...	$AgCl_2$	1792.9

Silver, Chlorate,	AgO,Cl^2O^5	2393.
— Cyanide,	$AgCy^2$	1674.8
— Fluoride,	AgF^2	1585.1
— Iodide,	AgI^2	2935.7
— Nitrate,	AgO,N^2O^5	2124.7
— Phosphate, *basic*,	$3AgO,P^2O^5$	5241.1
— — *neutral*,	$2AgO,P^2O^5$	3791.4
— Sulphate,	AgO,SO^3	1950.4
— Sulphide,	AgS	1550.4
Soda, anhydrous,	NaO	389.7
— Hydrate,	NaO,H^2O	502.2
— Acetate, *cryst.*,	$NaO,C^4H^6O^3+6Aq$	1702.2
— Borate, *cryst.*,	$NaO,2BO^3+Aq^{10}$	2387.1
— — *anhydrous*,	$NaO,2BO^3$	1262.1
— Carbonate,	NaO,CO^2	664.7
— — *cryst.*,	NaO,CO^2+Aq^{10}	1789.7
— Bicarbonate, *cryst.*,	NaO,H^2O+2CO^2	1052.2
— Nitrate,	NaO,N^2O^5	1064.8
— Phosphate, *cryst.*,	$H^2O,2NaO,P^2O^5+Aq^{24}$	4484.
— —	$H^2O,2NaO,P^2O^5$	1784.
— Pyrophosphate,	$2NaO,P^2O^5$	1671.5
— — *cryst.*,	$2NaO,P^2O^5+10H^2O$	2796.5
— Sulphate,	NaO,SO^3	890.5
— — *cryst.*,	NaO,SO^3+Aq^{10}	2015.5
— Hyposulphite, *cryst.*,	$NaO,S^2O^2+5H^2O$	1653.7
Sodium,	Na	289.7
— Protoxide,	NaO	389.7
— Peroxide,	Na^2O^2	879.5
— Chloride,	$NaCl^2$	733.
— Cyanide,	$NaCy^2$	614.8
— Fluoride,	NaF^2	525.2
— Fluo-Silicide,	$3NaF^2+2SiF^6$	3543.6
— Iodide,	NaI^2	1875.7
— Sulphide,	NaS	490.5
Strontian,	SrO	645.9
— Carbonate,	SrO,CO^2	920.9
— Nitrate, *anhydrous*,	SrO,N^2O^5	1321.
— — *cryst.*,	$SrO,N^2O^5+Aq^5$	1863.5
— Sulphate,	SrO,SO^3	1146.7
Strontium,	Sr	545.9
— Chloride,	$SrCl^2$	989.2
— — *cryst.*,	$SrCl^2+6H^2O$	1664.2
Succinic Acid, *cryst.*,	$H^2O,C^4H^4O^3$	737.5
Sulpho-Cyanogen,	Cy^2S^2	726.6
Sulphur,	S	200.8

Sulphur, *two atoms*,	S^2	401.5
Sulphuretted Hydrogen,	H^2S	213.3
Sulphur, Acids of—		
— Hyposulphurous Acid,	SO	300.8
— Pentathionic Acid,	S^5O^5	1503.8
— Tetrathionic Acid,	S^4O^5	1303.
— Trithionic Acid,	S^3O^5	1102.3
— Sulphurous Acid,	SO^2	400.8
— Hyposulphuric Acid,	S^2O^5	901.5
— Sulphuric Acid, *anhydrous*,	SO^3	500.8
— — *Hydrate*	H^2O, SO^3	613.3
Tantalic Acid	Ta^2O^3	
Tantalium	Ta	
Tartaric Acid, *anhydrous*,	$C^4H^4O^5$	825.
— — *cryst.*,	$C^4H^4O^5 + H^2O$	937.5
Tellurium	Te	801.8
— Telluric Acid,	TeO^3	1101.8
Terbium,	Tb	
Thorium,	Th	
Tin,	Sn	743.9
— Protoxide,	SnO	735.3
— Peroxide,	SnO^2	835.3
— Protochloride,	$SnCl^2$	935.3
— — *cryst.*,	$SnCl^2 + Aq^2$	1178.6
— Perchloride,	$SnCl^4$	1403.6
— Sulphide,	SnS^2	1621.9
Titanic Acid,	TiO^2	1136.8
Titanium,	Ti	501.6
Tungsten	W	301.6
Tungstic Acid,	WO^3	1150.8
Uranium,	U	1450.8
Vanadic Acid,	VO^3	742.9
Vanadium,	V	1156.9
Water,	H^2O or Aq	856.9
— Oxygenated	H^2O^2	112.5
Yttrium,	Y	212.5
Zinc,	Zn	406.6
— Oxide,	ZnO	506.6
— Chloride,	$ZnCl^2$	849.9
— Sulphate, *cryst.*,	$ZnO, SO^3 + 7H^2O$	1794.8
— Sulphide,	ZnS	607.3
Zirconia,	Zr^2O^3	1139.4
Zirconium,	Zr	419.7

ELEMENTARY EXPERIMENTS.

THE object of this set of Elementary Experiments is to render the student familiar with some of the more important chemical operations, without a knowledge of which he cannot proceed a step in safety. Being only introductory to the extended systematic course of experiments, their subjects are very simple. I have endeavoured to render them as easy of performance as possible; and I believe that, if the instructions are strictly followed, the student will meet with few difficulties.

The experiments are so contrived that they can be performed, either by a single student, or by a considerable number at the same time, working according to dictation. I make this remark to account for the precision of the details that are given under some heads, and the peculiarity of the style.

ALTERATION OF VEGETABLE COLOURS BY ACIDS AND ALCALIES.

a. Action of Nitric Acid on Blue Litmus.

Half fill a conical test glass with water.
Add to it three drops of diluted nitric acid.
Stir the mixture with a glass rod.
Dip into it a slip of blue litmus test paper.
Observe that the *blue* colour changes to *red*.
Put the stirrer to your tongue and *taste* the mixture.
You will find it to have a *sour* or *acid* taste.[1]

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[1] The test glass that is best adapted for these experiments, is of a conical shape with a lip. It is called Clark's Test Glass, fig. 1. Water in small quantities is conveniently supplied by means of the water-bottle, fig. 2. This apparatus consists of a glass bottle, to which two glass tubes are fitted by a cork. Through one tube, *a*, air enters the bottle, while water escapes through *b*, the other tube. It answers very well for giving a small quiet stream of water, for filling tubes, wetting papers, and the like.

2.

1.

b. Action of Nitric Acid on Yellow Turmeric.

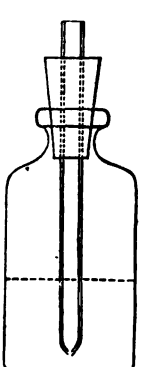
Take the diluted nitric acid prepared in Experiment *a*.
Dip into it a slip of yellow turmeric test paper.
Observe that the yellow colour remains unchanged.

The drops of acid are most conveniently added by means of a straight pipette, or narrow glass tube, open at both ends, usually called the dropping tube, fig. 3. It may be 6 inches long, and not less than ¼ inch in diameter, having a very small orifice but not a capillary point, at one end. See *Griffin's "Chemical Manipulation,"* from which the following quotation is made:—

3.

"In using such a tube in testing, it is seldom necessary to suck with the mouth. On dipping the tube into the test, a portion enters, more or less of it, according to the depth of the dip. As much as may be required is allowed to enter, and is retained by applying a moistened finger to the top of the tube,—and just as much as may be wished is allowed to drop into the solution under examination, by a partial or complete removal of the finger.

"A modification of this method of applying tests by dropping tubes, may be advantageously employed where a large number of students in a class are furnished with solutions for analysis, and are all to apply the same tests to their solutions. Two-ounce bottles should be provided with large and good corks, perforated and fitted with pieces of straight glass tube of the width represented in the margin, and so long as to rise half an inch above the cork, and to descend nearly to the bottom of the bottles. The lower end of the tubes may be a little contracted. The test solutions are to be put into these bottles, and the tubes used to remove them as required. The cork must stand so high above the bottle as to be easily caught by the thumb and middle finger of the right hand, while the forefinger is left at liberty to close or open the upper part of the tube, as may be required. The tests are under complete control in this apparatus, so that any quantity which an experiment may demand, can be administered with facility. When a very small quantity of the re-agent is required, you lift the tube without closing its upper end. It then acts like a glass rod, and takes up only a drop or two. When you want a larger quantity, you lift the tube out of the liquid, close the upper end by your forefinger, plunge the closed tube into the liquid, and remove your finger. The air in the bottle then presses the liquid up the tube con-



4.

5.

c. Action of Ammonia on Yellow Turmeric.

Half fill a conical test glass with water.
Add to it three drops of Liquid Ammonia.
Stir the mixture with a glass rod.
Dip into it a slip of yellow turmeric test paper.
Observe that the *yellow* colour changes to *brown*.
Put the stirrer to your tongue and *taste* the mixture.
You will find it to have an *acrid* or *alcaline* taste.

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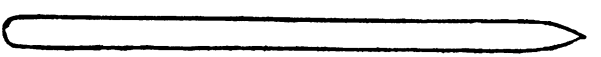
siderably higher than the level in the bottle. The tube can then be lifted with what it contains."

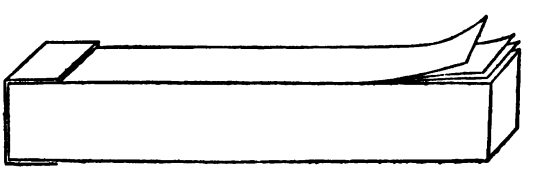
Another excellent form of bottle for containing liquors to be used in testing, is shown by fig. 6. It has a wide mouth, and, instead of a stopper, is furnished with a glass cap, ground to fit the outside of the neck. It is also provided with a pipette, the orifice of which is so small that it cannot deliver above one drop of liquor at a time, though, at the pleasure of the operator, it can give many drops in succession. The pipette always remains in the bottle. Of course, it is always ready for use, requires no cleaning, prevents the waste of the reagent, and is an effectual check on the overdosing of any liquor that is to be tested.

6.

Every test glass should be accompanied by a stirrer of the size and form of fig. 7.


7.

The slip of test paper may be 2½ inches long, ½ inch wide. Such slips are to be had bound up in little books, like banker's cheque books, fig. 8.


8.

The test papers made of this size are coloured carefully for delicate testing. When the purpose for which they are used is merely demonstrative, as in Lectures, it is better to use larger papers more strongly coloured, that the changes of colour may be easily seen at a distance. Such test papers are now prepared for sale.

d. Action of Ammonia on Blue Litmus.

Take the diluted ammonia prepared in Experiment *c*.
Dip into it a slip of blue litmus test paper.
Observe that the blue colour remains unchanged.

e. Counter-Actions of Nitric Acid and Ammonia.[1]

Take the diluted nitric acid prepared in Experiment *a*.
And the diluted ammonia prepared in Experiment *c*.
Dip into the acid a slip of blue litmus test paper.
Dip the reddened paper into the ammonia.
Observe that the *redness* disappears and the *blue* colour returns.
Dip into the ammonia a slip of yellow turmeric test paper.
Then dip the brown part into the acid.
Observe that the brown colour disappears and the yellow colour returns.

f. Action of Carbonate of Soda on Red Litmus.

Take a slip of red litmus test paper.
Wet it with water from the water bottle.
Put on the wet paper a crystal of carbonate of soda.
Observe that the *red* colour changes to *blue*.

g. Action of Carbonate of Soda on Yellow Turmeric.

Take a slip of yellow turmeric test paper.
Wet it with water from the water bottle.
Put on the wet paper a crystal of carbonate of soda.
Observe that the *yellow* colour changes to *brown*.

h. Other Counter-Actions of Acids and Alcalies.

Half fill a conical test glass with blue cabbage liquor.[2]
Add to it a few drops of diluted sulphuric acid.
Observe that the *blue* colour changes to *red*.
Take a straight pipette in your left hand.
Take up in the pipette some solution of potash.

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[1] Instead of nitric acid, you may take muriatic, sulphuric, acetic, or oxalic acid; and instead of ammonia you may take caustic potash or caustic soda, for these experiments. The effects produced by the reagents of each set will be similar.

[2] To prepare blue cabbage liquor, chop up some leaves of blue cabbage, pour boiling water over them, and after some hours decant the blue liquor for use. It soon becomes mouldy, but can be preserved by adding to it as much oil of vitriol as will make it strongly red. When required for use, a solution of soda or potash must be added to neutralise the acid.

Add the potash gradually to the coloured liquor.
Stir the mixture with a glass rod held in your right hand.
Observe that the *red* liquor regains its *blue* colour.
And that with more potash it becomes *green*.
With another pipette take diluted sulphuric acid.
Add it gradually to the green mixture.
Stir the mixture with a glass rŏd.
Observe that the *green* colour changes first to *blue*, and finally to *red*.

Results of these Experiments:

i. We have demonstrated,—
That blue litmus is changed to red by acids.[1]
That yellow turmeric is not changed in colour by acids.
That brown turmeric is changed to yellow by acids.
And from these demonstrations, we draw the general conclusion, that *acids change blue litmus to red, and brown turmeric to yellow.*
We have also found, that acids or substances which change blue litmus to red, have a peculiar *sour* or *acid* taste.

k. We have demonstrated,—
That yellow turmeric is changed to brown by alcalies.
That red litmus is changed to blue by alcalies.
That blue litmus is not changed in colour by alcalies.
And from these demonstrations we draw the general conclusion, that *alcalies change red litmus to blue, and yellow turmeric to brown.*
We have also found, that alcalies, or the substances which change red litmus to blue, have a peculiar *acrid* or *alcaline* taste.

l. The experiments on the counter-actions of acids and alcalies, prove that these bodies have the faculty of *neutralising each other's power.* Hence, acids restore colours that have been altered by alcalies, and alcalies restore colours that have been altered by acids.

m. As respects the *application* of the knowledge derived from these experiments, I may remark, that when a substance reddens blue litmus, it is said to be *acid;* when it makes red litmus turn blue, or yellow

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[1] These conclusions presuppose that the reactions have been tried, as suggested in Note [1] page 34, with a few other acids and alcalies than those named in the text. It would hardly be right to draw sweeping general conclusions from the behaviour of one acid and one alcali towards the coloured tests; yet it would have been tedious to put more experiments in the text. The student can increase or vary the examples at pleasure.

turmeric turn brown, it is said to be *alcaline*. But the possession of this acid property is not sufficient to constitute what chemists call AN ACID, nor is the possession of the alcaline property sufficient to constitute AN ALCALI; because the power of altering vegetable colours is possessed by some substances which, properly speaking, are neither acids nor alcalies—as, for example, carbonate of soda, used in Experiment *f*. This substance is *a salt*, containing both carbonic acid and soda, that is, both an acid and an alcali. It cannot, therefore, be called *an acid*, nor yet *an alcali*, but it can very properly be said to be *alcaline*, for this term describes simply a property which the substance actually possesses, namely, that of alcalinity. There are other salts which contain both an acid and an alcali, and which, nevertheless, manifest an *acid reaction* on vegetable colours. Many salts of the metals have this property, and they are said to have *an acid reaction*. There is a third class of salts that have *no* action on vegetable colours, and that are neither acid nor alcaline in taste. Common salt is an example of this kind. Such substances are said to be *neutral*.

BLEACHING OF VEGETABLE COLOURS BY CHLORINE.

a. Bleaching of Blue Cabbage Liquor.

Put into a conical test glass a little blue cabbage liquor.
Add to it a few drops of solution of chlorine.[1]
Stir the mixture with a glass rod.
The colour of the cabbage liquor is destroyed, and the mixture becomes white.

b. Bleaching of Indigo.

Half fill a conical test glass with water.
Add to it a few drops of sulphate of indigo.
Stir the mixture with a glass rod.
Add to it a small quantity of solution of chlorine gas,
Or of a clear solution of bleaching powder.
Stir the mixture with a glass rod.
The blue colour disappears and is succeeded by a pale greenish yellow.

c. Bleaching of Litmus Paper.

Half fill a conical test glass with solution of chlorine.
Dip into it a slip of blue litmus test paper.
Observe that the blue colour is bleached to white.

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[1] A solution of chlorine gas in water can be preserved for some time in a good state for use, if closely corked up in an opaque bottle of salt-glazed stoneware. Directions for preparing the solution will be given under the head of Chlorine.

d. Bleaching of Pink Paper.

Take the solution of chlorine used in Experiment *c*.
Dip into it a slip of pink paper.
Or use any kind of paper stained with vegetable colours, or unbleached calico, or any kind of cloth tinged by colours of vegetable origin.
Observe that the colour is almost immediately destroyed (bleached).

e. Result of this Experiment :—Chlorine destroys vegetable colours. The experiment illustrates the art of bleaching cotton cloth by means of chlorine.

CHEMICAL METAMORPHOSES.

WHEN certain chemical bodies are placed in contact under particular circumstances, they combine together and produce new compounds possessed of new properties. These changes are evidenced to the eye by changes of colour and form, of taste and smell, of temperature and of bulk, which frequently are of a very surprising nature. The experiments adduced in proof of these facts will not, I hope, be considered out of place in a work devoted to CHEMICAL "RECREATIONS."

EXPERIMENTS WITH COLOURED LIQUIDS.

To produce a beautiful Green Liquid by mixing a Blue one with a Colourless one.

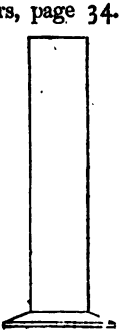
To produce a beautiful Crimson Liquid by mixing a Blue one and a Colourless one.

To change the Colour of a Liquid from Green to Red, by adding a Colourless one to it.

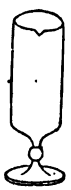
To make the same Liquid alternately Red and Green by the addition of two Colourless Liquids.

The methods of producing all these effects are detailed in Process *h*, on the Reactions of Acids and Alkalies with vegetable Colours, page 34.

A Liquor which is Crimson at the bottom, Purple in the middle, and Green at the top.—Nearly fill a tall cylindrical glass with water, and colour it blue by adding a tablespoonful of tincture of cabbage—then make it green at the top by gently adding a little liquid ammonia, and afterwards introduce a little sulphuric acid by means of a pipette, or glass tube, long enough to reach to the bottom of the vessel; upon which the effect above mentioned will be produced. If you stir the mixture with the glass tube, it will be blue, green, or red, according to the predominance of one or other of the ingredients. See page 35. If you add a little liquid chlorine, the colour will be totally destroyed. Page 36.



9.



10. *Three different Colours produced from the same vegetable infusion by the addition of three Colourless Liquids.*—Into each of three test glasses put a little diluted blue tincture of cabbage. To one add a solution of alum, to the second a solution of potash, and to the third a few drops of muriatic acid. The product of the first mixture will have a purple colour, that of the second a bright green, and that of the third a beautiful crimson.

A beautiful Blue Liquid produced by mixing two Colourless ones.—Add a few drops of a solution of nitrate of copper to a glass of water—the mixture will be colourless if sufficiently dilute: pour a little liquid ammonia into it—the mixture will then assume a fine blue colour.—*Rationale.* The alcali precipitates the copper, and then re-dissolves it, forming a blue solution of the ammonia-nitrate of copper.

To produce a Colourless Liquid by mixing a deep Blue one with a Colourless one.—Add a little nitric acid to the blue liquid produced in the preceding experiment: upon which the colour instantly disappears.—*Rationale.* The blue compound is decomposed, and nitrate of ammonia and nitrate of copper are formed. These salts remain in solution in the water, the quantity of which renders the blue colour of the nitrate of copper insensible.

Coloured Liquors which become Colourless on the addition of a Colourless Liquor.—A solution of chlorine in water, or a solution of chloride of lime, deprives all vegetable solutions of their colour. Page 36.

ACTION OF ACIDS AND ALCALIES ON A VARIETY OF VEGETABLE COLOURS.—These experiments may be performed in conical test glasses or small test tubes.

Brazil Wood.—Boiled in 16 times its weight of water. A deeply-coloured red liquor. Alcalies turn it purple or violet. Iron salts turn it brown. Caustic potash in 200,000 parts of water acts upon it. Strong acids make it bright rose-red. Sulphuric acid has the most powerful action. The acid red liquor is a fine colour for prints on paper, but it injures the paper. Sulphurous acid bleaches it. Some of the weaker acids turn it yellow.

Paper saturated with Indigo dissolved in sulphuric acid.—Chlorine bleaches it. Boiling nitric acid does the same. Chromates and bromides bleach it cold. Iodides do the same, but leave a red stain on the paper that gradually disappears in the air.

Litmus.—Solution in water or alcohol. Blue. Acids redden it. Alcalies restore the blue colour.

Rhubarb infused in water. A bright yellow solution. Alcalies turn it reddish-brown. Very readily affected.

Rose leaves macerated in alcohol. Yellowish-brown liquid. Alcalies turn it green. Acids made it rose-red. The changes of colour in this solution are effected by an exceedingly small portion either of acid or alcali.

Turmeric.—Infusion in water, or tincture in alcohol. Yellow liquids. Alcalies turn them reddish brown.

Violets.—A violet liquor. Alcalies turn it green and acids red.

Logwood.—Gives a brownish decoction. Acids render it yellow or reddish. Alcalies give it a splendid purple colour. If a drop of a solution of logwood and another of liquid ammonia are put on the same plate, but at a distance from each other, the vapour of the alcali very soon changes the colour of the logwood.

TWO LIMPID LIQUORS CONVERTED BY MIXTURE INTO A SOLID MASS.

11.

Process 1. If a saturated solution of chloride of calcium be mixed with a saturated solution of carbonate of potash, both of which are transparent liquids, the result is the formation of an opaque and almost solid mass. Mutual decomposition of the salts takes place—chloride of potassium and carbonate of lime are formed; and the latter absorbs the whole of the water of solution, and produces a degree of solidity.

Process 2. Drop sulphuric acid into a saturated solution of chloride of calcium; in this case also an opaque mass is produced.—The chloride of calcium is decomposed, and sulphate of lime, a highly insoluble salt, is formed.

Process 3. Pour a saturated solution of caustic potash into a saturated solution of sulphate of magnesia (Epsom salt), a nearly solid mass is produced. The sulphuric acid leaves the magnesia (which then combines with water and is precipitated in the form of a white powder) in order to combine with the potash.

If a little nitric acid be added to the product of *Process* 1, the solid mass will be converted into a transparent liquid: the insoluble carbonate of lime being converted into the soluble nitrate of lime.

A solid white powder produced by mixing two colourless liquids.—This is an effect of common occurrence in chemical experiments. See the article on *Precipitation*. The solids produced by the mixture of different liquids are of every variety of colour and form, and it is a very amusing and instructive exercise, to examine the effect of various precipitating agents on different metallic solutions. I shall add an example in the *test for muriatic acid.*—Add a drop of muriatic acid to a quart of water; pour some of the mixture into a test glass, and let fall into it a single drop of a solution of nitrate of silver—the whole will instantly be pervaded by a milkiness, because the chlorine of the muriatic acid combines with the silver and forms chloride of silver, a salt highly insoluble. So great is the power of this test, that if a single grain of common salt is dissolved in 42,250 grains of water, the muriatic acid is detected, though amounting to only 1 part in 108,333 of the weight of the solution.

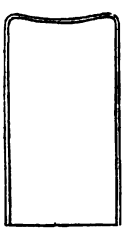
A fluid produced by rubbing together two solid metals.—Triturate an amalgam of lead with an amalgam of bismuth—the product will be

fluid, like mercury. Fluids are likewise produced when any of the mixtures which follow are triturated; acetate of lead and sulphate of zinc—or, sulphate of soda and nitrate of ammonia—or sulphate of soda and carbonate of potash.—These salts should be all fresh crystallised.

A green coloured solid produced by mixing a blue one with a white one.—Triturate crystallised sulphate of copper with crystallised super-acetate of lead. In this process, acetate of copper, which has a green colour, is formed.

To make a solid green paint by mixing a blue liquor with a colourless liquor.—Add to a hot solution of blue sulphate of copper, a little solution of colourless carbonate of soda—a beautiful powder, known by the name of French green, will be precipitated.—The powder is a subcarbonate of copper. The liquor may be separated by filtration.

Two pungent and invisible gases unite and form an inodorous solid.—*Process* 1. Fill a jar with ammoniacal gas, and another with muriatic acid gas, in the manner described in a subsequent part of this work. Apply the two jars mouth to mouth, and the above-mentioned effect will instantly be produced, chloride of ammonium being formed and precipitated on the sides of the jars.



12.

Process 2. Dip a clean feather into muriatic acid, and moisten with it the interior of a glass such as is depicted by fig. 12, and in like manner moisten the interior of a similar glass with liquid ammonia. The glasses, in this state, will seem empty, but if they be put mouth to mouth together, the whole included space will be filled with a dense white vapour; which in the end settles on the sides of the glasses in the form of a white powder, solid chloride of ammonium.

Process 3. If two jars, one containing ammoniacal gas, and the other containing carbonic acid gas, are thus put together, solid carbonate of ammonia will be formed.

Two highly-odorous liquids produce a mixture totally without odour.—Mix liquid ammonia with muriatic or nitric acid, till the resulting liquor is neutral. The smell of both the ingredients disappears, and the saline product has neither the acid nor the alcaline taste possessed by the two odorous liquids.

Two bodies devoid of odour produce a compound highly odorous and volatile.—Mingle together in a mortar equal parts of sal-ammoniac and quicklime. Tne mixture disengages ammoniacal gas, which has a very pungent odour.

To deprive a red rose of its colour, and to restore the colour again.—Hold a red rose over the blue flame produced by burning sulphur. You can do this by fastening the rose to the top of an inverted glass jar. This flame diffuses a gas which has the property of depriving vegetables of their colour. It is called sulphurous acid gas. Whenever it comes

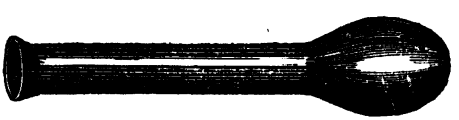
into contact with the rose, the colour is so discharged as to make the rose either beautifully variegated or entirely white. If you afterwards dip the rose into water its red colour is restored to it.

A substance which may be eaten, produced by the admixture of two powerful poisons.—A solution of muriatic acid and a solution of caustic soda are both poisonous. If mixed together in such proportions as to make a neutral solution, they produce common kitchen salt.

The method of making such mixtures in proper proportions, is explained in the article on Equivalent Test Liquors.

Explanation.—9½ parts of muriatic acid contain 9 parts of chlorine and ½ part of hydrogen. 10½ parts of caustic soda contain 6 parts of sodium, 4 parts of oxygen, and ½ part of hydrogen. When these quantities of the ingredients, in a state of aqueous solution, are mingled together, new combinations take place. 9 parts of chlorine and 6 parts of sodium, produce 15 parts of common salt, also called chloride of sodium; and 4 parts of oxygen and ½ part of hydrogen, produce 4½ parts of pure water. Thus nothing is lost or left at liberty. The chloride of sodium dissolves in the water at the moment of formation, but can be obtained in the state of crystals by evaporating the solution.

To Dissolve Metallic Copper in a Liquid.—Dissolve a grain of thin copper wire or foil in six drops of nitric acid, using a tube of the following form. Observe the effervescence that is produced; the pro-



13.

duction of red gas just above the liquor, the change of the liquor to green, the heat which is produced, the peculiar smell that is disengaged. In one minute the copper will be dissolved, the liquor remaining green. Blow into the tube by a smaller tube held in the mouth. This expels the red gas, and turns the green liquor blue. Alternately shake the tube and blow air into it, until the green colour and red gas no more return. The smell goes away with the gas. Look *into* the tube and not *across* it, to see the colour of the liquor and gas. Boil it next over a spirit lamp. White fumes of nitric acid go away. When the liquor gets thick and pasty, allow it to cool. It will form a mass of blue crystals, proceeding like rays from the centre. This is nitrate of copper. Apply heat; the crystals then melt, get drier, and stick about the sides of the glass as a hard cake. The salt now decomposes, and a strong smell of nitric acid is disengaged. When the bulb is cold, half fill it with water. Part of the hard matter dissolves, producing a blue solution of nitrate of copper; part remains undissolved as a bluish-green

powder. This is a nitrate with excess of base, which is insoluble in water. Add a single drop of nitric acid, and the whole will dissolve. With the resulting solution, you can apply the different tests for detecting copper, which are described under the head of Copper.

SYMPATHETIC INKS.

SYMPATHETIC inks are liquids which, being used for writing or drawing, form figures or letters, which, under certain circumstances, or after certain operations, become changed in colour, or from being illegible become conspicuous. Liquids of this kind known at present are very numerous, and the experiments executed with their assistance are some of the most entertaining which modern chemistry affords. Several varieties were known in very ancient times. We find Ovid teaching young women to deceive their guardians by writing billets to their lovers with new milk, letters formed with which are rendered legible by coal-dust or soot. And Ausonius proposes the same thing to Paulinus. Pliny, in whose time it was known that any colourless, glutinous juice would attract black powder as well as milk, recommends for this purpose the milky sap of certain plants.

There are several metallic solutions, entirely colourless, or having a very weak tint, which, if applied to paper, produce figures that remain invisible, either till washed with another colourless solution, or exposed to its vapour. Among these, there is none more curious or capable of exciting greater astonishment, than that which consists of a solution of sugar of lead, which becomes black on exposure to sulphuretted hydrogen gas, even at a considerable distance. The mountebank performers of mechanical tricks and chemical experiments, whom the people have been pleased to term conjurors, derive considerable aid from the service of bodies such as those under consideration. How potent must he appear to ignorant eyes, who causes a figure to grow, as it were, on a paper untouched by any hand, and exposed meanwhile to view! Yet, to do this, requires only that the person use the ink just named, and manage the business with a little dexterity.

Whatever is written with a solution of sugar of lead, with a clean pen, remains invisible while dry; but, when the writing is washed over with liquid sulphuretted hydrogen, it becomes instantly black. The most extraordinary circumstance is this, that, though sheets of paper without number, and even a board, be placed between the invisible writing and the reviving liquid, the same effect will take place as in the former case; the writing being turned black by a vapour which penetrates the substance of the wood and the folds of the paper.

It is instructive to look back upon the hypotheses which successive speculators set up to explain the causes of various effects observed in

nature. The phenomena which appeared to take place without any visible agency, were ascribed in the middle ages to certain "occult qualities." This doctrine gave way to the idea of magnetic effluvia, which was succeeded by a something termed sympathy; and sympathy itself was exploded by attraction and electricity. In future times our own method of tracing out causes will, no doubt, be reckoned as absurd as the ridiculous modes which have preceded it.

Another remarkable kind of sympathetic ink is that prepared from cobalt, the invention of which, though generally ascribed to Hellot, is affirmed by Pott to have been detailed by a German lady, very early in the seventeenth century. But it must be older than this, if it be true that, by means of this invention, Theophrastus Paracelsus could, in the same picture, represent alternately summer and winter. Such is the nature of this ink of cobalt, that the traces of it in writing or drawing are colourless when cold, but when moderately heated become of a beautiful green colour; which colour, however, vanishes as the paper cools, but can be made to reappear by a fresh application of heat.

I shall now mention a few of these inks out of the great number which but a slight acquaintance with chemistry will suggest to the student.—NOTE. The sympathetic inks may be laid on paper either with a camel-hair pencil or a common quill pen; but, whichever is used, it is necessary that the instrument be perfectly clean—the presence of the smallest quantity of any foreign body will go nigh to spoil the effect. The best thing to use is a clean fresh-cut quill pen.

1. Write with weak tincture of galls: the characters will be invisible. Moisten the paper with a feather, dipped in a weak solution of sulphate of iron—the writing will become black. To understand this phenomenon, you have only to know that a black liquid commonly termed ink is formed by adding infusion of galls to a solution of sulphate of iron.

2. Write with a weak solution of prussiate of potash—the letters will be invisible. Moisten the paper, as in the preceding experiment, with a weak solution of sulphate of iron—the writing will assume a fine *blue* colour.—*Rationale.* Prussian blue is here formed.

3. Wash paper with a solution of sulphate of iron, and suffer it to dry: when written upon this paper, dilute solution of prussiate of potash produces *blue* letters, and tincture of galls *black* ones; but upon common paper they make colourless marks.

4. Most acids, diluted and written with, leave marks which are invisible till the paper is heated, when they become *black*; the heat concentrating the weak acid, and enabling it to char the paper.

5. Write with a dilute solution of nitrate of silver, and let the writing dry *in the dark*—it will be invisible; fold up the paper, so as to keep the writing in the dark—it will continue invisible; but, expose the writing to the light of the sun—it will become *black*.—*Rationale.* The

nitrate of silver has the property of being decomposed by light; a black colour being acquired by the metallic oxide.

6. Characters written with a solution of equal parts of sulphate of copper and sal-ammoniac, have a *yellow* colour when heated, but are invisible when cold.

7. Write with a dilute solution of chloride of copper. The writing is invisible when cold, but *yellow* when heated.

8. Write with a dilute solution of chloride of gold, and dry the writing in the dark—it will be invisible. Moisten the paper, by means of a feather or bit of sponge, with a solution of chloride of tin—the writing will then assume a purple colour, occasioned by the presence of a minute portion of the purple precipitate of Cassius, a compound of tin and gold.

9. Write with a solution of nitrate of bismuth—the writing will be invisible. Immerse the paper in water—the characters will then be legible.—*Rationale.* The water decomposes the salt, and causes a white compound of bismuth to be precipitated in a solid form.

10. Expose a paper upon which you have written with nitrate of bismuth, to the vapour of water impregnated with sulphuretted hydrogen—the writing will become black. It is the property of bismuth to be thus affected by sulphuretted hydrogen. The black substance is sulphide of bismuth.

11. Let a paper upon which you have written with nitrate of bismuth be moistened with solution of prussiate of potash the writing will assume a beautiful *yellow* colour; cyanide of bismuth being formed.

12. Write with a solution of sulphate of copper—no writing will be visible. Wash the paper with solution of prussiate of potash—the writing will then get a *reddish-brown* colour; cyanide of copper being formed.

13. Write with a solution of acetate of lead—the writing will be invisible. Hold the paper over a saucer containing liquid sulphuretted hydrogen—the writing will become, first black, and then glittering like silver. The metallic salt is here decomposed by the sulphuretted hydrogen, which produces black sulphide of lead.

14. Upon a fire-screen let there be drawn a representation of winter, with trees destitute of foliage, and ground covered with snow. Let, however, every part of the picture which, if the scene represented summer, would be green, be covered with the sympathetic ink, produced by dissolving zaffre or impure cobalt in aqua regia, which is a mixture of nitric and muriatic acids. Draw, for instance, leaves on the trees, and grass on the ground. These marks will not be visible; the picture will still bear the aspect of winter. But, let the fire-screen be placed for a short time near the fire, *then* the view will exhibit all the verdure of summer. When allowed to cool, the verdure disappears; but

it may be again revived, by the same means as before, and that as often as is desired, provided the paper be not heated beyond a certain point; for, if heated too much, the ink will assume a permanent brown colour. A solution of pure chloride of cobalt will not answer the above purpose, as it gives a blue and not a green sympathetic ink. The green tint is due to the presence of arsenic and iron among the impure cobalt.

15. A jar is filled with clear water. A piece of white pasteboard is put into it. The whole may be then covered from view. After a few minutes, the white pasteboard is taken out, and found to have an inscription upon it in blue letters. *Explanation:* The clear water is a weak solution of iodide of potassium, mixed with a few drops of sulphuric acid. The white pasteboard has had the writing previously made upon it with starch paste. Such writing is invisible on white pasteboard; but in the experiment, a blue compound is formed by the combination of iodine and starch.

14.

My youthful readers will probably not take it amiss if I add here a few other examples of

CHEMISTRY FOR HOLIDAYS.

Such of them as visit the Polytechnic Institution, may like to know how they can imitate the wonderful exploits performed in that and similar establishments for public entertainment; some few of these popular experiments do not depend solely upon philosophical principles, but are aided in some degree by sleight of hand. It is not my business to teach the art of conjuring, but it is impossible to explain these experiments without describing the extent of the trickery which forms part of them.

The Enchanted Bottle.—The conjuror's bottle from which you pour when required, water, milk, blue dye, port wine, sherry, or champagne, is a popular experiment, akin to these depending on such chemical changes as have been described in the preceding section, but aided by a little trickery.

As the experiment is usually performed, the conjuror seems to pour from the same black bottle into different wine-glasses, all the above liquors in the order in which the audience demands them.

The bottle contains actually but one liquor, which is a solution of sulphate of iron, containing both protosulphate, and persulphate, and a little free sulphuric acid. This mixture is put into a black wine bottle, because it has a brown colour, which the audience ought not to see. The trickery is chiefly with the wine-glasses, in which are placed beforehand small quantities of such chemical reagents as suffice to produce the desired changes of colour. These reagents are as follow:—

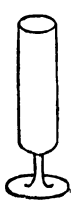
For *water*, nothing. The slight colour of the liquor is not recognized in the wine-glass. For *milk*, a solution of chloride of calcium, or chloride of barium. For *blue dye*, solutions of red and yellow prussiate of potash mixed. For *port wine*, a solution of sulpho-cyanide of potassium. For *sherry*, a very small quantity of the same. For *champagne*, a solution of bicarbonate of soda.

All these solutions should be as strong as possible, the entire inside of the glass should be wetted with them, just before the experiment is performed, but there should be as little as possible of the reagents left in the glasses, and that should be hid by a finger of the hand that holds the glass. Duplicates of each prepared glass should be ready, in case a second glass of any one sort should be demanded by the company.

The volatile plum-pudding.—At dinner, when the cover is removed from the plum-pudding, the pudding leaves its dish and rises to the ceiling of the dining-room.

Explanation.—The pudding is a sham one, consisting of a globular balloon, about six inches in diameter, painted with spots like a plum-pudding, and filled with hydrogen gas. Under the head of HYDROGEN, I shall give full instructions for preparing the gas, and filling balloons.

Loaf-sugar contains charcoal.—Place a large test glass upon a plate.



15.

Half fill the glass with lumps of loaf-sugar and put over them as much hot water as will thoroughly moisten them. Then add about a quarter of a fluid ounce of oil of vitriol. The mixture soon smokes, becomes black, and froths up. You may stir it with a glass rod. It sometimes rises over the edge of the glass, which is the reason that you must put the glass in a plate or a stoneware pan.

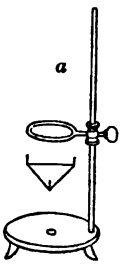
When the effervescence is at an end, you may wash the black mass into a large glass jar, and stir it up with a pint of water. It will be seen to contain a quantity of black powder. Let this settle; then pour off the acid liquor, and wash the powder with fresh water. If the powder is then collected and washed on a filter in a funnel, and afterwards dried, it will be found to be charcoal. The method of proving it to be charcoal will be decided in a subsequent experiment (page 59). Sugar consists of carbon, oxygen, and hydrogen. The oil of vitriol converts the oxygen and hydrogen into water, and leaves the carbon (or charcoal) free, and this substance being insoluble, is easily separable from the liquid products of the decomposition.

16.

Cambric handkerchiefs and fine lace consist of charcoal and water.—The composition of cotton and linen is analogous to that of sugar. They contain carbon, oxygen, and hydrogen, and they can be decomposed, like sugar, by warm oil of vitriol.

Fix a porcelain capsule of about 3 inches in diameter on a retort

stand, fig. 17, and put into it about half a fluid ounce of strong sulphuric acid. Place a spirit lamp below it to *warm* it, but do not make it *boil*, because the boiling of sulphuric acid is a dangerous operation, and the acid for this experiment requires only to be gently warmed. Put into the acid some small pieces of calico or linen cloth, and stir them about with a six-inch glass rod. The cloth will very soon be decomposed by the acid, as the sugar was in the preceding experiment. A similar black mixture is produced, from which, by washing in a large quantity of water, and afterwards on a filter, the charcoal can be obtained in powder.



17.

Vinegar is contained in dry wood.—If hard dry wood, oak, for example, or even a piece of dry cambric, is heated to redness in a glass tube closed at one end, in the manner described in a subsequent set of experiments on the identification of vegetable substances, the wood fibre will be decomposed, and a liquor will be expelled from it which contains vinegar, while charcoal in the solid form will remain behind in the glass tube. See pages 58 to 64.

A metal that takes fire when it touches cold water.—This is a property of the metal called potassium, which is extracted from the alcali potash. This metal is soft, lighter than water, and as brilliant as silver. It is preserved from the air in mineral naphtha, a liquid which contains no oxygen. A small globule, about a quarter of an inch in diameter, being thrown upon the surface of water contained in a flat pan of 9 to 12 inches diameter, immediately takes fire and burns with a violet-coloured flame and a hissing noise, swimming rapidly about the liquor and ending with a slight explosion. In this experiment, the potassium decomposes the water, sets free some hydrogen which burns with flame, and combines with the oxygen and part of the hydrogen to produce caustic potash, which dissolves in the water and renders it alcaline, as may be shown by means of red litmus test paper, which it turns blue.

A Fountain of Fire—formed by Phosphuretted Hydrogen Gas.—Put 15 grains of finely granulated zinc, and 6 grains of phosphorus, cut into small pieces under cold water, into a conical glass. Mix, in another glass, a drachm by measure of sulphuric acid, with two drachms of water. Now, take the two glasses into a dark room, and there pour the diluted acid over the zinc and phosphorus in the other glass: in a short time phosphuretted hydrogen gas will be produced, and beautiful jets of bluish flame will dart from all parts of the surface of the liquid, the mixture will be quite luminous, and a quantity of beautiful luminous smoke will rise in a column from the glass. A *Fountain of Fire* is a very apt name for the appearance that is produced. The experiment is very easily performed, and is a very beautiful one. But the operator must take care not to burn him-

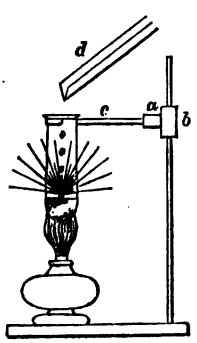
18.

self. The phosphorus must always be kept in cold water. It must not be touched by the fingers unless when it is covered by cold water. Burns from it are painful and difficult to heal.

Coloured Flames.—Coloured alcohol flames are best produced by forming a wick of asbestus filaments, fixing it in a glass tube, and moistening it with the concentrated saline solution that is intended to communicate the colour to the burning alcohol. A cotton wick soaked in a strong solution of the salt can be also made use of. In either case the wick is to be put into a common glass spirit lamp, containing spirits of wine. The solutions which give a colour to flame are those of chloride of strontium, boracic acid, chloride of barium, nitrate and muriate of copper.

A stream of oxygen gas directed upon a spirit lamp, coloured in this manner, produces an intense coloured flame.

The Fire Cloud.—Mix 5 parts of chloride of strontium with 1 part of nitrate of copper. Saturate about a pint of alcohol or pyroxilic spirit with these mixed salts. Put this into a metallic fountain, condensing into it a quantity of air by a syringe. A small jet being affixed, the mixture is pressed out with considerable force. If allowed to play upon the roof of a room, and there kindled, a brilliant cloud of variegated fire is produced.



Brilliant Deflagration.—Use the apparatus shown in the following vignette. It consists of a thin hard Bohemian glass tube, 3 inches long and nearly 1 inch wide. It is supported by a narrow crook of tin-plate, *c*, fixed by means of a cork, *a*, into the sliding socket of a tube-holder, *b*. As much nitrate of potash is used as fills about half-an-inch of the tube when melted. The heat of a small spirit lamp is sufficient for this quantity. When the nitrate of potash is in fusion, remove the lamp, and put a basin of water below the tube: then, by means of a slip of tin-plate, *d*, pour into the tube a small quantity of well-dried charcoal powder. Remove your hand instantly: a splendid combustion will occur in the tube. If the tube breaks, the contents fall into the water and do no harm.

In the same manner a small bit of sulphur, or of phosphorus, may be deflagrated. The latter should not exceed the eighth of an inch in diameter.

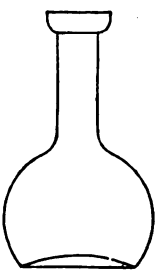
In these experiments, the combustible bodies combine energetically with the oxygen that is set free from the fused nitrate of potash.

The holiday amusements being over, we return to the philosophical consideration of our science.

EXAMPLES OF CHEMICAL OPERATIONS.

SOLUTION.

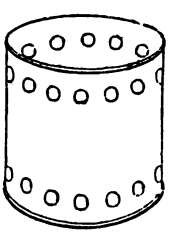
Take a two-ounce flat-bottomed solution bottle, fig. 19. Put into it a quarter of an ounce of alum in coarse powder. Add half an ounce, by measure, of water.[1]



19.

20.

Light your spirit lamp. Push down the wick till the flame is not above an inch long. If you use gas, make the flame of the same size. Hold the bottle with your right hand two or three inches above the flame. As soon as you see dew formed on the bottom of the bottle, wipe it with a dry cloth. Again hold the bottle over the flame, and again wipe off the dew. Move the bottle continually to keep the flame from heating one spot only, which would cause the bottle to break.



21.

22.

Now place the stone-ware furnace cylinder round the lamp, to make the flame burn steadily. Put the wire trellis upon the top of the cylinder, and the bottle upon the trellis, exactly over the lamp. Lift the bottle occasionally, and gently shake it with a circular motion, to agitate the powder in the liquid.

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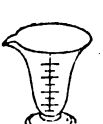
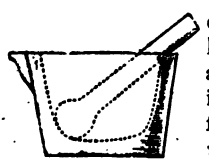
[1] For the weighing of solids, you will require a set of small apothecaries' scales and weights. For measuring liquids, a glass measure graduated from a drachm to an ounce (eight drachms).



In a short time the water boils, and the alum disappears; that is to say, the water *dissolves* the alum. Extinguish the flame by putting on the cover of the lamp. Allow the solution to cool.

While it is cooling,[1] I will explain to you a few chemical terms relating to the operation of solution. A solid which thus disappears in a liquid is said to be *soluble* in it. The liquid in which it dissolves is called the *solvent* or *menstruum*. The resulting liquid is a *solution*. When the solution contains as great a quantity of the solid matter as it is capable of dissolving, it is *saturated*. A solution is *known* to be saturated when fresh solid matter of the same sort, on being put into it, *remains undissolved*. When a saturated solution is mixed with pure water, it is said to be *diluted*.

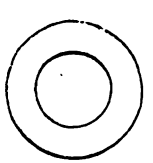


23.

Take a small porcelain mortar, two inches in diameter. Put into it a quarter of an ounce of kitchen salt. Half fill the mortar with water, and grind the salt in the water till the latter is saturated, which will be the case in a very few minutes. But if all the salt disappears during the grinding, you must add more to the same water, till you find the water to be saturated, and unable to dissolve any more salt.

24.

Allow the mixture to settle. Pour the clear part of it into a porcelain evaporating capsule of 3 inches diameter. Only half fill the capsule. Light your spirit lamp. Put round it the furnace cylinder. Place on the cylinder the perforated iron plate, fig. 25. Put the capsule in the perforation. Let all rest thus till the solution boils. Then put into the solution dry powdered kitchen salt, and see if it dissolves in the boiling solution. Watch the salt at the bottom to see if it diminishes in bulk; and watch also the solution at the top, to see if any change takes place there.



25.

You will observe two results:—1st, That the additional salt does not dissolve;—2nd, That as the water of the solution diminishes by evaporation, the salt previously dissolved in it is reproduced in the solid form.

We now return to the solution of alum, which some time ago was left to cool.

If it is cold, you will find that a portion of the alum is deposited in it in the solid state.

We are enabled by these experiments to draw the following—

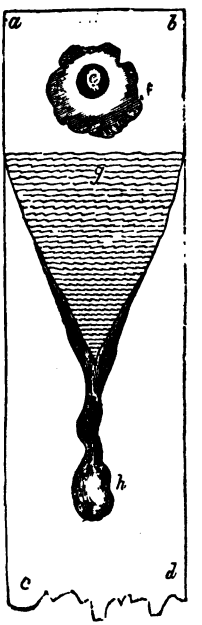
[1] The teacher is supposed to be dictating, and the students to be performing the experiments; hence the peculiar phraseology of this section.

Inferences respecting the Solubility of Alum and Salt.

a. Alum dissolves in larger quantity in hot water than it does in cold.

b. Kitchen salt dissolves equally well in hot water and cold water.

You perceive in this difference of solubility a chemical character whereby alum is distinguished from kitchen salt.



26.

EVAPORATION.

It is necessary to prove to you that when a hot saturated solution of alum deposits a quantity of solid alum upon becoming cold, it does not deposit the whole of its alum.

Take a slip of window-glass an inch wide and six inches long. Hold this by one end in a flat position. Place upon it, near the other end, a drop of distilled water, so as to make a mark about half an inch in diameter, as I now show you, [see the mark *f* in the margin.]

Light your lamp, and warm the drop of water over the flame till it all flies off in steam. It will leave no solid residue.

Upon the same glass slip, put a similar drop of the clear liquor that rests above the solid alum in the solution bottle. Warm this drop over the lamp till the glass is again dry. You will observe that a solid white substance is left upon the glass where the drop of solution was warmed. This solid white substance is alum.

In the operation of solution, a solid is made to disappear in a liquid. In the operation just performed, the reverse is the case; for here a liquid is made to disappear by means of heat, and the solid that was dissolved in it resumes its visible form. This operation is termed *evaporation.*

PRECIPITATION.—TESTING.

You can prove by another experiment, that the supernatant liquor in the solution bottle contains alum.

Take a conical test-glass and a glass rod. Pour into the glass a few drops of the liquor from the solution bottle. Add to it *Liquid Ammonia*, a few drops at a time, and stir the mixture with a glass rod after each addition of ammonia. When, after being stirred, the liquor in the test-glass smells of ammonia, enough of the latter has been added.[1]

[1] The young student must take care not to smell at ammonia incautiously, as it may produce much pain.

Observe that the effect produced by the addition of ammonia to the liquor presumed to contain alum, is the production of a solid substance having a white colour and a gelatinous consistence, which sinks slowly to the bottom of the test glass.

The substance thus produced is alumina, and its appearance proves that the clear liquor above the crystals still contains alum.

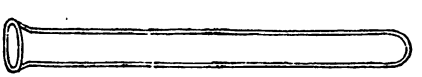
This application of any given chemical substance to prove the presence of another, by causing a particular phenomenon to take place, is termed *Testing*. The substance thus added is termed a *Test*, sometimes a *Reagent*. When the product happens to be, as it is in this case, a solid substance, the operation is called *precipitation*, the solid produced thus, a *precipitate*, and the liquid employed to produce it, a *precipitant*.

There is another test by which the presence of alum in the clear liquid can be made manifest by precipitation.

Take a conical test glass and a glass rod. Pour into the glass a few drops of the clear liquor resting above the crystals of alum in the solution bottle. Add to it a few drops of a clear solution of *Chloride of Barium*. Stir the mixture with the glass rod. You will observe that a white powder is produced. The chemical name of this powder is sulphate of barytes.

DISSOLVING POWER OF DIFFERENT LIQUIDS.

Take a test tube of the form I now show you, in size about six inches long, and half an inch wide. Fill an inch of it with water. Put into



27.

it a piece of camphor the size of a pea. Light your spirit lamp. Hold the tube near the mouth, by the thumb and second finger of the right hand, close the mouth by the application of the forefinger. Hold the bottom of the tube about three inches above the flame of the lamp. Gradually bring it down till it touches the top of the flame. Keep it there for one minute.

The closing of the tube by the forefinger must take place *before* you apply heat. It is too late when the heat is applied. The use of it is to retain a certain quantity of air in the tube, above the liquid. This air becomes condensed at the top of the tube, by the steam that is produced, and keeps the tube cold enough to be held by the fingers. But if the forefinger is removed for an instant, the air escapes, hot steam rushes forth, and the tube is made too hot to be held.

The camphor will not dissolve in the hot water.

Pour off the water. Add to the camphor, as much strong spirit of wine as fills an inch of the tube, and again expose it to a boiling heat.

The camphor dissolves in the spirit of wine.

Add to the solution of camphor, in alcohol, twice its bulk of water. Close the mouth of the tube with the forefinger; shake the mixture; then let it settle.

You will observe that the camphor is precipitated, that is to say, is reproduced in the solid state.

Hence camphor is insoluble in water, soluble in alcohol, but insoluble in diluted alcohol.

Take a similar test tube. Put into it half the bulk of a pea of pounded alum. Fill half an inch of the tube with alcohol. Boil the mixture over the spirit lamp.

You will find that the alum will not dissolve.

Yet you found that alum dissolved readily in water.

Here, then, is a chemical difference between alum and camphor, in respect to solubility. Alum dissolves in water, but not in alcohol. Camphor dissolves in alcohol, but not in water.

You will observe that these experiments show it to be necessary, in speaking of the solubility of a substance, to name the liquid in which it is soluble; and in speaking of its solubility in any particular quantity of the liquid, to name at what temperature the solution is effected, whether at the usual temperature of the air, or at a boiling heat.

CRYSTALLISATION.

Take a flat glass plate. Put upon one end of it a drop, as large as a sixpence, of the saturated solution of kitchen salt, prepared in a former experiment (p. 50). Light your spirit lamp. Hold the drop of solution over the flame till the edges of the drop begin to look white and dry, then remove it from the flame and let it cool.

You will observe, that in proportion as the water flies off in steam, the kitchen salt resumes the solid state, in the form of *cubes* or *dice*.

Take another glass plate. Put upon it a drop of the liquor produced by cooling the hot solution of alum, prepared in a former experiment (p. 49). Boil this drop of solution for an instant over the spirit lamp, then remove it and let it cool.

You will observe that the salt will be deposited in the solid state, in the form of square and triangular pyramids, larger in size than the little dice deposited by the kitchen salt.

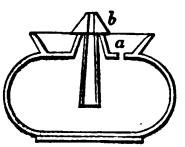
Take a bit of nitre, the eighth part of an inch in diameter. Powder it, and put it on the end of a flat glass plate. Add a drop of water, sufficient to spread as wide as a sixpence, over the nitre. [See letters *e* and *f* in the figure in p. 51.] Apply below it the flame of a spirit lamp. The nitre will soon dissolve and form a solution. Retain the solution in a moderate heat till it begins to look dry at the edges. Then remove it from the flame and let it cool.

You will observe that the salt will be deposited, in this case, under a

form, differing both from that of the kitchen salt and of the alum. It will appear like many masses of fibres, all radiating from centres, as do the spokes of a wheel, or the bones of a lady's fan.

I recommend you to repeat these experiments at your leisure, upon larger quantities of the three salts; and for this purpose, I shall give you the following directions:—

CRYSTALLISATION OF KITCHEN SALT.—Take half an ounce of kitchen salt. Dissolve it in water, by grinding it with water in a porcelain mortar, as was done in a former experiment (p. 50). Pour the solution from the mortar into a glass tumbler, and let any solid matter settle to the bottom. Then pour the clear solution into a porcelain capsule of 4 inches diameter. Light a small oil lamp,[1] containing sweet oil, and with the wick cut so short, that it burns without smoking. Put the furnace cylinder around the lamp, and the perforated iron plate upon the cylinder; fix the capsule in the perforation.



28.

The flame of the lamp should not be much more than half an inch long, otherwise the heat will be too strong, and the evaporation too rapid. The object to be gained, is to evaporate the water continually, but slowly.

Kitchen salt being equally soluble in hot and cold water, it can only be separated from its solutions by the evaporation of its water. The slower this evaporation takes place, the larger and the more complete in their form are the solid pieces of salt, the *dice* before spoken, which are produced in the course of the process. The solid pieces of determinate form thus produced in aqueous solutions, in consequence of the abstraction of part of the water, are in chemical language termed *crystals*. They are geometrical figures, possessing a certain number of plane surfaces, and consequently a certain number of edges and angles. The form which is assumed by kitchen salt, when slowly separated from its solution, is that of the *dice* or *cube* which I now show you.

29.

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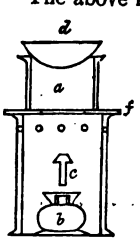
[1] The above figure represents a stoneware oil lamp, useful for slow evaporations. *b* represents the wick-holder. At the upper part is a cup for collecting the oil that overflows during the combustion, and for returning it, by the hole *a*, into the lamp.

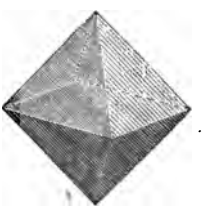


30.

The annexed figure exhibits a mode of effecting a slow evaporation: *b* is the lamp, *c* the wick-holder shown apart, *f* the perforated iron-plate, resting on the lamp cylinder, and supporting an extra stoneware cylinder *a*. The capsule containing the solution to be evaporated is marked *d*.

CRYSTALLISATION OF ALUM.—In the same manner as directed in the preceding article, prepare and evaporate a solution of half an ounce of alum. Be again careful to evaporate slowly, and do not allow the solution to boil. When the evaporation has been carried so far that a thin film, or skin, begins to appear on the surface of the solution, you are to remove the capsule from the lamp, and set it aside upon a thick woollen cloth or cushion to cool.

The film which appears upon a solution when undergoing concentration by evaporation, marks the stage at which the hot liquor is perfectly saturated with the salt, and at which, if deprived of any more of its water, it will begin to deposit a corresponding quantity of its salt At such a stage, if the solution contains *a salt less soluble in cold water than in hot*, it will, if allowed to cool slowly, deposit in crystals a quantity of salt equivalent to the reduction of temperature, and these crystals will be the more perfect in proportion to the slowness with which the cooling is permitted to take place. Now, alum is a substance of this character, and if its solution is brought to a proper state of concentration, and permitted to cool with a proper degree of slowness, it will produce crystals bearing a resemblance to the figure which I now show you—a figure not unlike two Egyptian pyramids joined base to base, and which in scientific language is called an *octahedron*. It is an approximation, more or less near, to this form, which produces the little square and triangular pyramids which appear when a drop of solution of alum is evaporated upon a slip of glass (p. 53).



31.

You find, therefore, in the result afforded by the careful crystallisation of alum and kitchen salt, another character which serves to distinguish these two substances from one another. Namely, that whereas the faces of the crystals of alum are triangular, those of the crystals of kitchen salt are square; and that whereas a perfect crystal of alum possesses *eight faces*, a perfect crystal of kitchen salt possesses only *six*. The first is an octahedron, the last a cube.

I showed you that when a hot solution of alum was cooled, a certain quantity of alum was deposited, but not all that the water held in solution. This is a constant result in similar operations. The liquor left above a mass of crystals produced by concentrating or by cooling a hot solution, is, in all cases, still a cold saturated solution of the salt in question; for only so much of the salt separates in crystals from the cooling liquid as cannot be held in solution at the diminished temperature. Consequently, on pouring off the liquor from a mass of crystals, and again subjecting it to evaporation and to cooling, a second crop of crystals can be procured from it. And by carrying as far as possible this alternate heating and cooling of the solution, you may separate in

crystals nearly the whole quantity of the salt held in solution. The technical term for a liquid poured off from a deposit of crystals, is the *mother-liquor*.

By the solution, evaporation, and crystallisation of half an ounce of nitre, performed exactly in the same manner as the last experiment with alum, you will obtain crystals of nitre in long *six-sided prisms*.

A similar experiment made with *sulphate of soda* will produce crystals that are *four-sided prisms*.

The evaporation of a drop of the solution of sulphate of soda upon a flat glass plate, readily produces four-sided prisms, mostly so very flat as to resemble knife-blades. In general they are radiated, but not in so decided a manner as the crystals of nitre described in a former experiment.

EFFLORESCENCE.

If you dry the crystals of sulphate of soda on the glass plate by pressing a bit of paper upon them, and then expose them on the glass to dry air for an hour, you will find that they will lose their transparency, turn white, and fall to powder. This phenomenon is called *efflorescence*. It occurs when crystals which contain water of crystallisation readily part with it to dry air. Most of the salts of soda are of this kind.

DELIQUESCENCE.

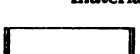
Take half an ounce each of dry carbonate of potash and crystallised carbonate of soda, both in fine powder. Expose them in two separate weighed porcelain capsules to the free air for at least a day; then weigh them again. The carbonate of soda will be found to have *lost weight*. The carbonate of potash to have *gained* weight. The air of the atmosphere takes water *from* the carbonate of soda, or, as it is said, causes it to *effloresce*; but it gives water *to* the carbonate of potash, or causes it to *deliquesce*. Deliquescent salts are difficult to crystallise and easy to dissolve.

EFFERVESCENCE.

32.

Take a conical test glass. Half fill it with water. Put into it two pieces as big as a pea of chalk or of carbonate of soda. Then add a few drops of muriatic acid. You will immediately observe a sort of boiling up, which in chemical language is termed *effervescence*. This effect is produced by the production, and escape through the water, of a quantity of gas.

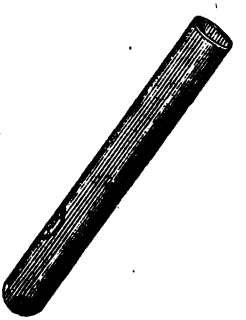
If you perform this experiment with larger quantities of materials than is mentioned here, it is proper to place the conical glass in the middle of a flat-bottomed glass capsule. In that case, when the acid boils over, it does not soil the table.



33.

SUBLIMATION.

Sublimation is a process by which volatile substances are converted by heat into vapours, and by the withdrawal of heat again condensed into solids. In small experiments undertaken to prove that a substance will sublime when heated in close vessels, or that, when it sublimes, it produces a particular kind of vapour, as respects its colour or smell, or that it produces crystals: or in experiments made to ascertain whether a substance is volatile or not, or whether or not it can be converted into a volatile substance; in these, and many other analytical cases of sublimation, it is now common to use no other apparatus than a glass tube closed at one end, and formed of very infusible glass. The substance to be sublimed is placed at the bottom of the tube, and is then exposed to heat. The sublimate, if any is produced, condenses upon the upper part of the tube, and is there examined. The quantity of matter taken for such an experiment need not in general be more than will lie upon this figure.

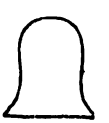


34.

35.

These general directions will enable you to comprehend readily the following experiments:—

1. Spread a small quantity of grossly-powdered gum-benzoin on the bottom of a porcelain basin, invert over it a glass tumbler, and apply to it a gentle heat by means of the lamp-furnace: the gum will melt, and dense fumes will immediately rise from it and deposit themselves on the sides of the glass in beautiful silky crystals of benzoic acid.



36.

2. Take a large glass jar, containing at its top a sprig of rosemary or some such shrub, and invert it over a flat thick piece of heated iron on which coarse powder of gum-benzoin has just been spread—then, the benzoic acid which rises, as in the preceding experiment, will be deposited on the branches of the shrub, producing a singular and beautiful representation of hoar frost.

3. Put a little camphor on a tin plate. Invert a conical test glass over it. Apply the heat of a spirit lamp below. The camphor readily sublimes.

37.

4. Put a grain of iodine into a small flask, or glass tube, and apply heat. Splendid violet vapours of iodine soon fill the tube. When the sublimation of iodine is effected slowly, crystals are formed.

5. Sublime a grain of cinnabar in a tube one-third of an inch wide.

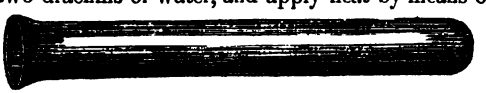
6. Sublime a grain of calomel in a similar tube. These two mercurial compounds will be found to be less easily volatilized than camphor, iodine, benzoic acid, and some other substances.

7. Put a grain of red oxide of mercury into a very small glass tube, and apply heat till the red oxide is entirely volatilized. Metallic mercury will condense on the sides of the tube, and oxygen gas escape at the mouth.

DISCRIMINATION OF VEGETABLE, ANIMAL, AND MINERAL BODIES.

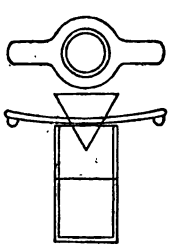
A.—Some of the properties of Nitrate of Potash, as distinguished from Carbonate of Potash.

Prepare the nitrate of potash as follows:—Take a test spoonful[1] of it in powder. Put it into a test tube half an inch wide by 3 or 4 inches long; add two drachms of water, and apply heat by means of the spirit



38.

lamp. If the solution thus produced is turbid, filter it through a small paper filter, supported in a filter ring laid on a beaked tumbler. The filter is not to be washed, nor the solution to be diluted.



41.

1. Put a few drops of the solution of nitrate of potash into a conical test glass. Add two or three drops of nitric acid. There will be no effervescence, and no visible change.

40.

2. Put into a similar conical test glass, a few drops of a concentrated solution of carbonate of potash. Add two or three drops of nitric acid. There will be a strong effervescence, and a discharge of colourless inodorous carbonic acid gas.

39.

[1] The test spoon is made of German silver. The bowl of it is hemispherical, and about a quarter of an inch in diameter. A *test spoonful* is as much of anything as can be conveniently lifted and carried in this spoon without spilling any of it. I use this term instead of the more indefinite term, a "*small quantity*." The handle of the test spoon is formed into a spatula, and serves for mixing powders with fluxes, in blowpipe experiments, &c.

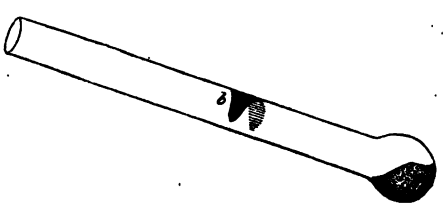
3. Put a few drops of the solution of nitrate of potash into a conical test glass. Add two or three drops of a solution of nitrate of lime. Stir the mixture with a glass rod. No change will take place.

4. Put into a similar conical test glass a few drops of a solution of carbonate of potash. Add two or three drops of a solution of nitrate of lime. Stir the mixture with a glass rod. An abundant *white precipitate* will appear. Add a few drops of nitric acid, and again stir the mixture. The white precipitate will effervesce and disappear.

5. *Results of this Experiment.*—The student is furnished with a process by which he can always distinguish *carbonate* of potash from *nitrate* of potash. The use of this will be shown presently:

B.—Some of the Properties of Charcoal.

Light your spirit lamp. Take a bulb glass tube of this size: [represented by the engraving, fig. 42.] Hold it by the open end. Warm it over the flame to dry it. Take a piece of charcoal the size of a pea, that is to say, a ball of a quarter of an inch in diameter. Put it



42.

into the tube. Hold the tube with the thumb and middle finger of the right hand in a horizontal position, or nearly so. Close the mouth of it with your forefinger, and heat the bulb over the flame till the charcoal becomes red hot.

1. Now observe,

That water appears upon the inner sides of the neck of the tube.

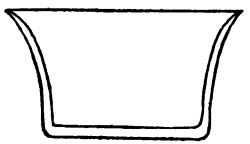
That the charcoal remains apparently unaltered.

2. Push a narrow slip of blue litmus test paper into the tube so as to become wetted by the water.

Do the same with a slip of red litmus or of yellow turmeric test paper.

Observe that the water expelled by heat from charcoal produces no change in these vegetable colours. It is, in fact, merely hygroscopic moisture, and is neither acid nor alcaline.

3. Take a small thin porcelain cup one inch in diameter, and fix it



43.

upon a thin wire triangle over the flame of a spirit lamp. Instead of the porcelain cup, you may use a very short glass tube closed at the bottom, or still better, a platinum cup one-third of an inch or half an inch in diameter. If the latter has a handle, it may be held by means of the small tongs, p. 61. If not it may be supported on a very thin iron triangle.[1]

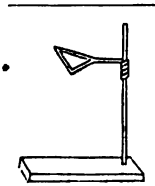
44.

Into this vessel put a test spoonful of nitrate of potash. Light the lamp and bring the nitrate of potash into full fusion. Then, without removing the flame, add to the melted nitre a few pieces, each as big as a pin's head, of the charcoal that was previously heated in the glass tube. You will observe that DEFLAGRATION takes place, that is to say, explosion accompanied by fire, within the cup; and that the charcoal swims about red hot on the nitre, and finally disappears.

4. When the porcelain cup is become nearly cold, half fill it with water, and boil the water to produce a solution of the substance, afforded by the deflagration of the charcoal in the nitre. If you use a platinum cup, it can be put into a glass tube and boiled with the water. Filter the resulting solution in the manner described at Exp. A, page 58.

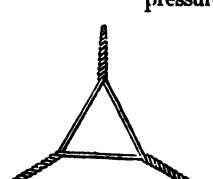
5. Put a few drops of this solution into a conical test glass. Add two or three drops of nitric acid. There will be a strong effervescence.

6. Put a few drops of the solution into a conical test glass. Add two or three drops of a solution of nitrate of lime. There will be a white precipitate. Add to this two or three drops of nitric acid, and stir the mixture with a glass rod. The precipitate now dissolves with effervescence.



45.

[1] The fixing of the cup at a proper distance above the flame, is effected by means of the *retort holder*, which consists of a perpendicular metal rod, a wooden foot, and a horizontal arm of thin brass wire, terminated at one end by a triangle, and at the other by a coil, which runs on the perpendicular rod, and which can be fixed at any height above the foot, by simple pressure upon the triangle. The size of the triangle can be diminished by smaller triangles of very fine wire, bent as I now show you (fig. 46), and placed across the larger triangle.



46.

The porcelain cup can also be fixed above the spirit lamp by means of the cylinder of the lamp furnace. A flat iron top is put on the cylinder, and a fine iron triangle placed upon it. The cup is then fixed in the triangle.

7. Support a splinter of the same charcoal before the flame of the blowpipe,[1] or near the edge of the spirit lamp; holding it on a piece of platinum foil, or in a platinum cup held spoon-fashion by means of the platinum tongs.

47.

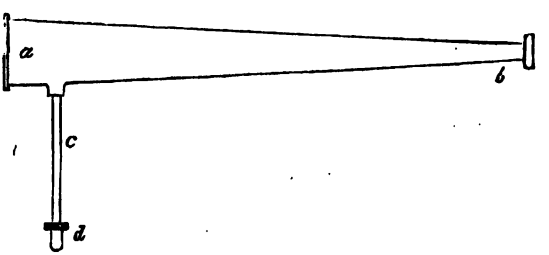
Observe that the charcoal burns without flame, gradually diminishes in size, and finally disappears, except a very small quantity of a white incombustible ash.

Result.—Experiments B, 3 to 6, in conjunction with Experiments A, 1 to 5, prove that the deflagration of nitre with charcoal changes NITRATE *of Potash* into CARBONATE *of Potash*.

C.—NATURE OF VEGETABLE BODIES.

1. Take a piece of dry writing paper an inch square. Crush it up into a lump the size of a pea. Put it into a glass tube, such as that in

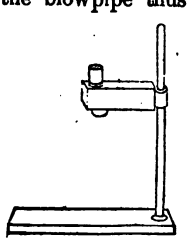
[1] The sort of blowpipe to be used in these experiments is represented in the following figure. For instructions as to the method of



48.

using it, I refer you to my "*Treatise on Chemical Manipulation*," wherein I have treated comprehensively of the use of this instrument.

I make no apology for introducing the use of the blowpipe thus early into an elementary course of experiments, because I am persuaded that such a course cannot be carried on cheaply and conveniently unless the blowpipe is made to replace the furnace as often as possible. Besides, there is no reason why the use of this instrument ought to be deferred. The presumed difficulty of learning to use it is quite imaginary, as I do not doubt it will be found by all who take the trouble to consult the work to which I have referred.



49.

The lamp used for experiments with the blowpipe is represented in the margin (fig. 49).

which you ignited the piece of charcoal, Exp. B. Take a slip of blue litmus test paper, and a slip of yellow turmeric test paper, and slightly moisten both of them with clean water, by means of the water bottle, page 31. Now ignite the piece of paper by holding the bulb of the tube in the flame of the spirit lamp. As soon as you see a white smoke in the tube, dip into it the blue test paper. After a moment take out the blue paper and put in the yellow paper.

2. Observe, that the white paper heated in the tube is converted into a black substance, preserving the same size and shape.

3. That a brown oily liquid is deposited on the sides of the tube.

4. That the blue test paper turns red, and that the yellow test paper remains unchanged, in the volatile matter given off during the ignition.

5. Fix a porcelain cup, by means of a wire triangle, over the spirit lamp. Melt in it three grains of nitre. Throw into the hot melted nitre, part of the black substance produced by the charring of the paper in the tube.

6. Observe that deflagration is produced, and that the black substance, after swimming about in the nitre red hot, finally disappears, precisely as the charcoal was observed to do in Exp. B, 3.

7. Boil water in the porcelain cup to dissolve the salt produced by the deflagration. Filter the solution without diluting it, and divide it into two portions in conical test glasses.

8. Add to one portion a few drops of nitric acid, which will occasion an effervescence.

9. Add to the other portion a few drops of a solution of nitrate of lime, which will produce a white precipitate; then add a few drops of nitric acid, and stir the mixture with a glass rod, whereupon the white precipitate will effervesce and re-dissolve.

10. Support the remainder of the black substance before the blow-pipe flame. Hold it upon platinum foil, or in the platinum cup. See B, 7.

11. Observe that it burns away without flame, and leaves nothing but a very small quantity of incombustible white ashes.

Inferences respecting the Nature of Vegetable Bodies, as exemplified by these experiments on paper.

a. They contain charcoal. The proof of this fact is afforded by the properties of the mixed black substance which is left when the paper is ignited in close vessels.

b. They contain the elements of a volatile acid, which acid they produce when subjected to the red heat in close vessels. This acid is vinegar.

This experiment will also enable you to understand the nature of the process by which vinegar is made from wood. Large iron vessels, fixed in a furnace, are filled with wood, and then shut close, with the excep-

tion of a pipe that is fixed into each of them. The fire is then lighted in the furnace, and the iron vessels are made red hot. Vinegar issues from the pipes, and when it is all passed out, the iron vessels are opened, and the wood is found to be converted into charcoal.

The vinegar thus produced is not in a pure state, but is mixed with the brown oily liquid that you found to condense on the sides of the glass tube during the ignition of the paper. It is freed from this liquid by subsequent operations.

D.—Nature of Animal Bodies.

1. Take a dried cochineal insect, or a bit of a feather. Put it into a glass tube. Prepare moistened slips of blue and yellow test papers. Ignite the insect by holding the tube in the flame of the spirit lamp, and put into the tube during the ignition, first the blue test paper, and then the yellow test paper. The ignition need not last longer than one minute.

2. Observe that the ignited insect is converted into a black substance like charcoal.

3. That a brown oily liquid is deposited on the sides of the tube.

4. That there is a strong smell of burnt oil and hartshorn.

5. That the blue test paper remains unaltered, and the yellow test paper turns brown.

6. Fix a porcelain cup upon the wire triangle over the spirit lamp. Melt in it three grains of nitre. Throw into the melted nitre part of the black substance produced by the ignition of the cochineal.

Observe that deflagration is produced, and that the black substance disappears.

7. The product of the deflagration, if dissolved and filtered will be found, by the process formerly given, section C, Nos. 7, 8, 9, to contain carbonate of potash.

8. Hold the rest of the black substance in the platinum spoon before the blowpipe flame.

Observe that it burns away without flame, and leaves only a very small quantity of white ashes.

9. *Inferences respecting the Nature of Animal Bodies, as exemplified by the cochineal insect.*

a. They contain charcoal.

b. They contain the elements of a volatile alcali, which alcali they produce when subjected to a red heat in close vessels.

These experiments enable you to understand the nature of the process by which *spirits of hartshorn* is made.

Hartshorn, or more commonly the bones of animals, is ignited in iron vessels, shut quite close, with the exception of a pipe to carry off gases. What passes out of the vessels during the ignition, is the volatile alcali, ammonia, in company with the brown oil which in your

experiment is deposited on the sides of the glass tube. Spirits of hartshorn is just such a mixture. The volatile alcali, ammonia, is spirits of hartshorn deprived of its brown oil.

The fetid smell produced in your experiment, arises not so much from the alcali, as from the brown oil, which contains a variety of odorous compounds.

The fixed matter that remains in the iron vessels, after this operation, is of a black colour. It is ground into powder, and sold under the name of *bone black*, or *animal charcoal*. When ignited in the open air, this black substance burns away partly, and leaves a white residue, commonly called *bone ash*. The part that burns away is charcoal. The white residue is phosphate of lime. This is the solid matter of all bones, but is not a component part of flesh.

E.—I do not intend to pursue the Analysis of Organic Bodies any farther; but the following facts I beg you to bear in recollection:—

1. A substance that gives off volatile matter when ignited in a glass tube, and leaves a charred residue that deflagrates with melted nitre, is almost invariably of organic origin.

2. If the volatile matter disengaged during the ignition turns blue litmus red, the substance is almost always of vegetable origin.

3. If the volatile matter turns yellow turmeric brown, the substance is almost always of animal origin, or if not so, it is one of those vegetable bodies that contain nitrogen.

4. A substance that does not char when ignited in a glass tube, nor give off volatile matter, nor deflagrate with melted nitre, is certainly derived from the mineral kingdom.

5. If a substance chars in a tube, gives off volatile matter, and affords a residue that deflagrates with nitre, yet will not burn entirely away when heated in a platinum cup in free air, then it consists partly of an *organic*, and partly of an *inorganic* substance; as, for example, of a vegetable acid combined with an earth, or of a metallic acid combined with a vegetable alcali.

6. Several mineral bodies give off water in the tube, or turn black when heated, or deflagrate with nitre, or burn entirely away in the open air; but no single mineral substance can exhibit all the phenomena which have been described, as characteristic of organic bodies.[1]

[1] *Substances to be given as Exercises on this Experiment.*—The teacher may give the student small quantities of some of the following substances for examination according to this process. Alum, salt, chalk, red lead, starch, ground rice, gum kino, peroxide of manganese, pounded charcoal, sulphur, acetate of lead, fibres of asbestus, fibres of cotton, fibres of silk, acetate of copper, with any kind of dried vegetable or animal substance.

QUALITIVE ANALYSIS OF SALTS.

I PROPOSE to give in this section a COURSE OF TESTING adapted for beginners. The course may be followed by a single student, using the book as his guide; but the experiments are such as can also be performed by a large number of students, each provided with a set of apparatus, and all working simultaneously, under the direction of a teacher.

The object proposed is to analyse a certain number of the compound bodies termed Salts, embracing those of the most important Acids, Alcalies, Earths, and Metals; and in order that the solution of the problem may not be rendered too difficult, only such salts are to be taken as will dissolve in water.

SUBSTANCES TO BE SOUGHT FOR.[1]

The instructions now to be given apply only to compounds which *dissolve in water*, and which *contain no other metals*, and *salts of no other acids*, than those I am about to name:—

These METALS—

1. Potassium.
2. Sodium.
3. Ammonium.
4. Barium.
5. Strontium.
6. Calcium.
7. Manganese.
8. Iron, protosalts.
9. Magnesium.
10. Cadmium.
11. Bismuth.
12. Zinc.
13. Tin, protosalts.
14. Aluminum.
15. Lead.
16. Tin, persalts.
17. Antimony.
18. Mercury, protosalts.
19. Cobalt.
20. Copper.
21. Nickel.
22. Chromium.
23. Iron, mixtures of persalts with protosalts.
24. Mercury, persalts.
25. Gold.
26. Iron, persalts.
27. Silver.

And these CLASSES OF SALTS—

1. Nitrates.
2. Chlorates.
3. Chlorides.
4. Iodides.
5. Arsenites.
6. Sulphides.
7. Fluorides.
8. Phosphates.
9. Arseniates.
10. Borates.
11. Oxalates.
12. Carbonates.
13. Sulphates.
14. Chromates.

[1] From this point the text may be read as instructions to those who are to make the experiments.

Any single salt, soluble in water, and containing one of these 27 metals and one of the acids of these 14 classes of salts, can be analysed by the method now to be described.[1]

---

[1] The teacher who gives out the salt to be examined takes care that these conditions are fulfilled, that the salt is pure, and that it contains no other substances than those I have enumerated.

Free acids and bases should not be given to pupils until they have had some experience in the testing of salts; because, in many cases, they do not, until neutralized, act towards the reagents in the same manner as their respective salts. And when they are for the first time given to the pupils, notice should also be given that free acids and bases may be found among the substances given for analysis.

LIST OF THE APPARATUS REQUIRED BY EACH STUDENT FOR THIS SET OF EXPERIMENTS.

a. Apparatus for Indicating Tests.

Small porcelain pestle and mortar.
Test spoon (German silver).
Flat-bottomed flask, to hold 1 or 2 ounces of water.
Pipette graduated to 25 septems.
Glass spirit lamp.
Cotton wick for lamp in a box.
Small brass tongs to trim the wick.
Lamp furnace cylinder with holes.
Trellis top for lamp furnace.
Box with 100 circular filters 2¾ inches diameter.
Filter-ring to hold the filter over a test glass.
Water bottle to supply water to tubes.
Glass funnel and support.
2 straight pipettes, small size.
8 conical test glasses with spout.
8 glass stirrers, 3 inch.
Rest for stirrers and pipettes.
Boiling tube, 6 inches by 1 inch.
Handle to hold the boiling tube while hot.
Book of red litmus test paper.
Book of blue litmus test paper.
Pair of tubes for testing with sulphuretted hydrogen.

9 capped bottles with pipettes (fig. 6, p. 33), about 2 oz. size, containing solutions of the following tests:—

Carbonate of Soda.
Liquid Ammonia.
Caustic Potash.
Red Prussiate of Potash.
Nitrate of Barytes.
Nitrate of Silver.
Nitrate of Lead.
Chloride of Calcium.
Nitric Acid.

2 wide-mouthed stoppered bottles with the following dry tests:—

Sulphide of Calcium.
Bisulphate of Potash.

b. Apparatus for Confirming Tests.—See page 83.

That you may have an idea of the compounds with which you must expect to meet, I now show you a list of salts, acids, and bases, that may be presented to you for analysis.

NITRATE OF
1. Potash.
2. Soda.
3. Ammonia.
4. Barytes.
5. Strontian.
6. Lime.
7. Magnesia.
8. Cadmium.
9. Bismuth.
10. Zinc.
11. Tin, protoxide.
12. Alumina.
13. Lead.
14. Tin, peroxide.
15. Mercury, protoxide.
16. Cobalt.
17. Copper.
18. Nickel.
19. Chromium.
20. Mercury, peroxide.
21. Silver.

CHLORATE OF
22. Potash.
23. Barytes.
24. Lime.
25. Silver.

CHLORIDE OF
26. Potassium.
27. Sodium.
28. Ammonium.
29. Barium.
30. Strontium.
31. Calcium.
32. Manganese.
33. Iron, proto.
34. Magnesium.
35. Cadmium.
36. Bismuth.
37. Zinc.
38. Tin, proto.
39. Aluminum.
40. Tin, perch.
41. Antimony.
42. Cobalt.
43. Copper.
44. Nickel.
45. Chromium.
46. Iron, mixed per- and protochloride.
47. Mercury, perchloride.
48. Gold.
49. Iron, perch.

IODIDE OF
50. Potassium.
51. Sodium.

ARSENITE OF
52. Potash.
53. Soda.

SULPHIDE OF
54. Potassium.
55. Sodium.
56. Ammonium.
57. Barium.
58. Calcium.
59. Potassium.
60. Silver.

PHOSPHATE OF
61. Soda.
62. Ammonia.

ARSENIATE OF
63. Potash.
64. Soda.

BORATE OF
65. Potash.
66. Soda.
67. Ammonia.

OXALATE OF
68. Potash.
69. Soda.
70. Ammonia.

CARBONATE OF
71. Potash.
72. Soda.
73. Ammonia.

SULPHATE OF
74. Potash.
75. Soda.
76. Ammonia.
77. Manganese.
78. Iron, proto.
79. Magnesia.
80. Cadmium.
81. Bismuth.
82. Zinc.
83. Alumina.
84. Cobalt.
85. Copper.
86. Nickel.
87. Chromium.
88. Iron, per- and proto-salts mixed.
89. Iron, perox.

CHROMATE OF
90. Potash.
91. Soda.

FREE BASES, *soluble in water.*
92. Potash.
93. Soda.
94. Ammonia.
95. Barytes.
96. Strontian.
97. Lime.

FREE ACIDS *in aqueous solution.*
98. Nitric.
99. Chloric.
100. Muriatic.
101. Hydriodic.
102. Arsenious.
103. Sulphuretted Hydrogen.
104. Hydrofluoric.
105. Phosphoric.
106. Arsenic.
107. Boracic.
108. Oxalic.
109. Carbonic.
110. Sulphuric.
111. Chromic.

PREPARATION OF A SOLUTION OF THE SALT.

You are now supposed to be furnished with a set of testing apparatus, with reagents, and with a salt intended to be analysed.[1] You are therefore ready to proceed.

The first thing you have to do is to make a *solution* of part of the substance for analysis.

Pulverize your salt in the small porcelain mortar, till it feels no longer gritty between the finger and thumb. Put the half of the powder upon the end of a slip of glazed writing-paper, and insert it, as I now show you,[2] into a one-ounce or two-ounce flat-bottomed solution flask. Next, pour into the graduated measure one drachm of water. Add this to the powder in the flask. Be sure not to spill any of the water on the outside of your flask, or if you *do* spill it, be sure and wipe the flask dry.

---

[1] *Advertisement to Teachers.*—The quantity of dry salt supplied for the first experiment may be 10 grains to each pupil; one half to be used in forming a solution for examination by the Indicating Tests; the other half to be kept in the solid state for examination by the Blowpipe, or by the Confirming Tests. The salt may be also presented upon the first occasion in its crystallised state, in order that the beginner may have the advantage of any information he can derive from the physical properties of the substance. In subsequent experiments, the quantity of the salts should be gradually reduced from 10 grains to 1 grain, and it should be presented in fine powder.

In some cases, and perhaps generally after the first two lessons, the compounds for examination may, in order to save time, be presented to the class in a state of solution, each pupil being furnished with a small bottle containing one or two drachms of the liquid that is to be tested. In this case, the teacher or his assistant prepares the solution previous to the assembling of the class, observing the precaution of making the solutions of the same strength that they would have been had they been prepared by the class individually, according to the instructions given in the text.

[2] *Method of inserting powders into deep narrow vessels.*—Take a long slip of highly-glazed writing-paper, as wide as the diameter of the mouth of the vessel into which the powder is to be inserted. Fold this longitudinally into a sort of gutter, and place the powder upon one end of it. Hold the vessel in a horizontal position, and insert the paper gutter into it, the end bearing the powder first. Then hold the vessel upright, upon which the powder falls from the paper to the bottom of the vessel. Withdraw the paper in such a manner as not to soil the deck of the vessel.

As the half of your salt is 5 grains, and the drachm of water is 60 grains, your solution will contain 1 in 12 of solid matter, which is a good proportion for most solutions.[1]

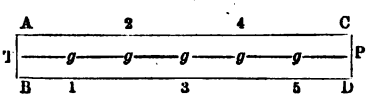
Light your spirit lamp.[2] Push down the wick till the flame is not above an inch long. Hold the flask over the flame. Move it gently round in a small circle about an inch above the flame, so as to warm all parts of its bottom, and to mix the powder with the water by the gyration. You will soon see dew formed on the bottom of the flask. Wipe the dew away with a cloth. Again hold the flask over the flame. Again wipe off the dew.

Now place the furnace cylinder round the lamp—put the wire trellis upon the cylinder, and set the flask upon the trellis, exactly over the flame. Lift the flask about once a minute, and gently shake it round, to mix the powder with the water. As you have different salts to

[1] *To the Teacher.*—As you lessen the quantity of solid matter, you must prescribe the application of less water, else the solutions will become too dilute. The proportion of 1 to 12 may serve as a general rule, though sometimes more water is necessary.

[2] When this lesson is to be taught to a number of students, and gas is at command, spirit lamps may be economically dispensed with.

A long plank, about a foot broad (or two feet broad if the locality permits it), and two inches thick, is supported horizontally with the surface at 33 to 36 inches above the floor. A gas-pipe is fixed upon the centre of the upper side of this plank, and runs its whole length. At 18 inches distance from each other there are upright jets rising from this gas-pipe, the whole of which are under the control of the teacher, who stands at one end of the plank, where there is a stop-cock to regulate the issue of the gas—



50.

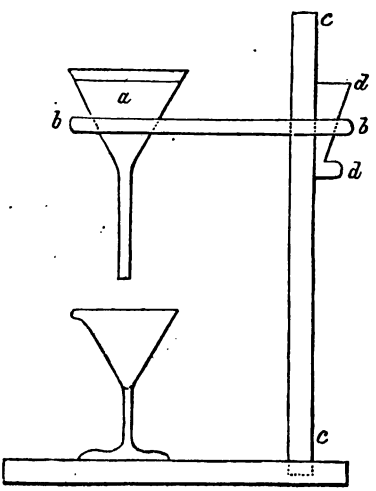
The lines A B C D represent the upper surface of the plank. P is the gas-pipe running down its centre; *g g g g g* represent the jets of gas. T is the position of the teacher, who is able to see everything that is transacted the whole length of the board. The pupils who are to be exercised in experimenting, stand on both sides of the board, one opposite to every gas-light, as shown by the numbers 1, 2, 3, 4, 5.

If stoneware furnaces (fig. 21, p. 49) are to be used to support vessels over the gas jets, the long gas-pipe must be sunk into the surface of the plank; or it may be affixed to the under surface of the plank, and the jets be passed up through the plank. Each jet may also be provided with a separate stop-cock, where the cost can be afforded.

examine, your solutions will not all be produced in the same time, for some salts require more water than others, and more time to dissolve. What I have now to say will therefore concern only some of you. In three or four minutes the water will boil, and if present in sufficient quantity will dissolve the salt. But if the salt, after two or three minutes' boiling, does not dissolve, you must remove the flask from the lamp, let the boiling cease, insert a funnel into the flask, and add half a drachm more water. Then boil again.

The solution being thus effected is next to be filtered. Extinguish the flame; let the solution cool; and, in the meantime, prepare your filter.

Take a funnel-holder. Fix the horizontal branch of it at six inches above the foot. Put into the horizontal branch a glass funnel of $1\frac{1}{2}$ inch diameter. Take a circular filter of $2\frac{3}{4}$ inches diameter. Fold it



51.

into a quadrant. Open one of the folds so as to make a cone. Place it in the funnel, and sprinkle water over the paper by means of the washing bottle, till it is made wet enough to sit close to the bottom of the funnel. There must be a space of one-eighth of an inch between the top of the filter and the edge of the funnel; that is to say, the filter must be so much smaller than the funnel. Place a conical ounce test glass below the neck of the funnel, as I now show you. [See the cut.] Now pour the solution from the flask into the filter. Take care not to pour in so much at a time as to rise above the top of the filter. When the solution is all run through the filter into the test glass, you have it prepared for testing.

CLASSIFICATION OF TESTS.

I divide Tests into two Classes. The *First Class* comprises those which are most general in their reactions, and which, on being applied in proper order to the solutions prepared for testing, serve to *indicate* the metals and acids which *probably* compose the compounds subjected to analysis.

The *Second Class* comprises those more particular tests which on being applied to a compound *presumed*, from the action of tests of the first class, to be composed of certain constituents, serve either to *confirm* or to *disprove* the presumed composition of the substance submitted to analysis.

The first class are called *Indicating Tests;* the second class *Confirming Tests.*

I.—INDICATING TESTS.

I shall begin with the *Indicating Tests*, which are of two kinds, such, namely, as serve to point out the *metals* contained in the salts, and such as point out the *acids.*

A.—TESTING FOR METALS.

The application of tests always commences with the application of the Indicating Tests for Metals. These are five in number, namely:—

1. Carbonate of Soda.
2. Liquid Ammonia.
3. Caustic Potash.
4. Red Prussiate of Potash.
5. Sulphuretted Hydrogen Gas.

The first four of these tests you have ready in solution; the last you will prepare at the moment when it is required. I proceed to tell you how these tests are to be applied.

52.

Experiment 1.—Pour six drops of the solution of the unknown salt into a conical test glass, fig. 52. Add to it three drops of *Carbonate of Soda.* Stir the mixture with a glass rod. If no precipitate appears, add three drops more of the carbonate of soda. Again stir the mixture.

You will get A PRECIPITATE or NO PRECIPITATE. In either case, you are to record the result on the ASSAY NOTE, which I now hand to you, and upon which you will find directions for filling up the blanks.[1]

[1] *To Teachers.*—The ASSAY NOTE affords an easy and effectual check on the pupil's carefulness of manipulation and power of observation. A

If Carbonate of Soda produces *no precipitate*, the metal contained in the salt is one of these three:

No. 1. Potassium.
2. Sodium, or
3. Ammonium.

In this case, you need apply none of the other Indicating Tests to your solution, for they can give no farther information. You will discriminate these three metals by means of the *Confirming Tests*, of which I shall speak after going through the set of indicating tests.

If, on the contrary, the carbonate of soda produces *a precipitate*, you write P on the Assay Note, and then proceed to apply the next test to your solution. The *colour* of the precipitate produced by carbonate of soda is of no importance in the present case, and need not be marked on the Assay Note.

Experiment 2.—Pour six drops of the unknown solution into another test glass, and add six drops of *Liquid Ammonia*. Stir the mixture.

If *no* precipitate is produced, the metal contained in the salt is

No. 4. Barium.
5. Strontium, or
6. Calcium.

How to discriminate these three metals, I shall show you hereafter by means of *Confirming Tests*. You can get no farther information respecting any of them from the Indicating Tests.

If, however, you get *a precipitate* with Liquid Ammonia, you write P on your Assay Note, and proceed to the next reagent. In the present case, as in the last, the *colour* of the precipitate need not be marked on the Assay Note.

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contrivance of this kind is quite essential when the number of pupils is so considerable that the teacher cannot readily see what every one of them is doing. Suppose that 20 students are engaged in simultaneous Testing. They are furnished with 20 different substances selected from the list given at page 67, and numbered 1 to 20. They are also provided with printed copies of the Assay Note, which at the conclusion of the Lesson are returned to you, duly filled up and subscribed by the 20 different analysts. As you know beforehand what ought to be written in every vacant space of each Assay Note, it is, of course, easy to check either an inaccurate experiment, or an erroneous deduction.

The superintendence of such a class, and the examination of the Assay Notes, can be intrusted to an assistant, provided he be furnished with a set of Assay Notes, filled up to correspond with the indications that would be afforded by all the substances enumerated at page 67.

ASSAY NOTE, No.

TESTS FOR THE METAL.

Carbonate of Soda	
Ammonia	
Potash	
Red Prussiate of Potash	
Sulphuretted Hydrogen	
METAL INDICATED	

TESTS FOR THE ACID.

Nitrate of Barytes	
Nitrate of Silver	
Nitrate of Lead	
Chloride of Calcium	
ACID INDICATED	

DIRECTIONS.—Against the word No. , write the number that is marked upon the envelope of the salt, or upon the bottled solution which is presented to you for analysis. Fill up the blank spaces opposite the names of the tests as follows:—If you get no precipitate, insert a cipher, o. If you get a precipitate, write P, and add the colour of the precipitate, thus: *P white*, or *P brown*. If the precipitate dissolves in an excess of the test, add S after the colour, as *P white S*, *P brown S*. When the metal and the acid are indicated, write their names in the spaces provided for that purpose. Sign your name below.

_____, *Analyst.*

*Date*_____

Experiment 3.—Pour six drops of the unknown solution into an ounce-test glass. Then take a quantity (one or two fluid drachms) of *Caustic Potash* in a dropping tube such as I now show you. Hold the dropping tube in your left hand, and let the potash fall, *one drop at a time*, into the solution under analysis. Stir the mixture with a glass rod after each addition of potash.

53.

You will, in this case, *be sure* to get *a precipitate*, and you have two things to observe in respect to it—first, what *colour* it has, and secondly, whether, subsequent to its first production by means of a *small* quantity of potash, it can be dissolved, or made to disappear, by adding a *larger* quantity of potash.

The *colours* of the precipitates produced by caustic potash are *white*, *black*, *blue*, *green*, *yellow*, and *brown*. The white precipitates are distinguishable into two varieties; those which *dissolve* in an excess of potash, and those which *do not*.

Although it is impossible to apply potash at this stage of the analysis without causing precipitation, yet it is very possible to add, in carelessness, too much of the potash at once, and so to render the resulting precipitate invisible at the instant of its production. This is the reason why I tell you to add the potash *gradually*, that you may see the precipitate when first produced, and notice its colour before it is re-dissolved.

Fill up your Assay Notes according to what you observe, write P for precipitate, then the name of the colour, and add S when the precipitate is soluble in an excess of the potash.

I proceed to notice the different kinds of precipitates produced in this experiment, beginning with those of a *white* colour.

The *white precipitates* that are *insoluble* in an excess of potash indicate these five metals:—

No. 7. Manganese.	No. 10. Cadmium.
8. Iron, its protosalts.	11. Bismuth.
9. Magnesium.	

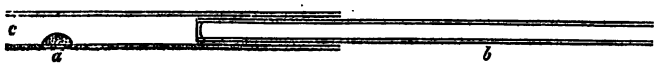
I have now to tell you how to distinguish these five metals from one another.

Experiment 4.—Take six drops of the unknown solution in a test glass, and add two or three drops of a solution of *Red Prussiate of Potash*.

A *Brown* precipitate indicates Manganese.
A *Blue* precipitate indicates Protosalts of Iron.
No precipitate indicates Magnesium.
Any other precipitate is to be disregarded.

This leaves Cadmium and Bismuth undiscriminated.
Fill up your Assay Note, and proceed to the next test.

Experiment 5.—Take a few drops of the solution in a test glass, and add to it a drop or two of nitric acid. Dip into the mixture the end of a small glass tube, *b*, fig. 54, so as to take up a small film of the liquor.



54

Expose this to the action of *Sulphuretted Hydrogen Gas* as follows:—

Mix together one part of a Sulphide of Calcium, and three parts of Bisulphate of Potash, and insert the mixture into a small glass tube, in the manner shown by fig. 54 *a*. The figure shows the size of the tube and also the quantity of salts necessary to be used. Put the tube *b* into its place, warm the mixture at *a*, by holding the tube over a flame, or by putting it for a moment into your mouth. Then blow gently into the tubes at the end *c*.

Sulphuretted hydrogen gas will be disengaged from the mixed salts in the tube *a*, will act upon the solution at the end of *b*, and throw a coloured precipitate on the sides of that tube.

Under the given circumstances the colour must be either yellow or black.

Yellow indicates Cadmium.
Black indicates Bismuth.

Experiment 6.—The *White precipitates* which were produced by caustic potash, and *re-dissolved* by an excess of that test, indicate six metals, namely:—

No. 12. Zinc.	No. 15. Lead.
13. Tin, its protosalts.	16. Tin, its persalts.
14. Aluminum.	17. Antimony.

To distinguish betwixt these metals, take a fresh portion of the unknown solution, and add to it a few drops of the solution of *Red Prussiate of Potash.*

A *Yellow-red* precipitate indicates Zinc.
A *White* precipitate indicates Tin, protosalts.
Any other precipitate gives no useful indication.

Experiment 7.—Take four drops of the unknown solution, mix with it one drop of nitric acid, and expose a little of the mixture to an atmosphere of *Sulphuretted Hydrogen Gas*, in the manner related in Experiment 5. If a precipitate is produced, observe its colour.

No precipitate indicates Aluminum.
A *Black* precipitate indicates Lead.
A *Yellow* precipitate indicates Persalts of Tin.
An *Orange* precipitate indicates Antimony.

Experiment 8.—The *Black precipitate* produced by potash indicates
No. 18. Mercury, its protosalts.

Sometimes, however, potash produces a *slight* black precipitate with Gold. These black precipitates can be discriminated thus:—

To a fresh portion of the unknown solution, add a few drops of *Red Prussiate of Potash.*

A *Red-brown* precipitate indicates Mercury.

No precipitate indicates Gold.

Experiment 9.—The *Blue precipitates* produced by potash indicate
No. 19. Cobalt, and
20. Copper.

These two metals are discriminated [1] as follows:—

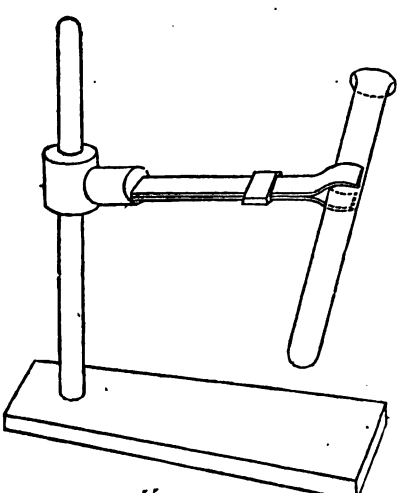
Pour both the solution and the precipitate into a small flask, or a test tube,[2] and boil the mixture over the spirit lamp till the precipitate changes colour.

If it turns *Red*, the metal is Cobalt.

If it turns *Black*, it is Copper.

Experiment 10.—The *Green precipitates* produced by potash indicate three metals, namely:—

No. 21. Nickel.
22. Chromium, and
23. Iron, mixtures of persalts with protosalts.



55.

[1] Most solutions of cobalt have a red colour. Those of copper are blue or green.

[2] The annexed figure represents a tube-holder, an instrument by which a tube or small flask can be readily supported over a spirit-lamp flame, when a solution is to be boiled. The arm that holds the tube moves round in the socket that is affixed to the upright rod, so that the tube can be held in any desired position.

Another holder for tubes and flasks is shown on page 77.

You discriminate these three metals as follows:—

To a fresh portion of the unknown solution, add a few drops of a solution of *Red Prussiate of Potash.*

A *Yellow-green* precipitate indicates Nickel.
No precipitate indicates Chromium.
A *Light-blue* precipitate indicates Iron.

Experiment 11.—The *Yellow precipitates* produced by potash indicates two metals, namely:—

No. 24. Mercury, persalts.
25. Gold.

These are discriminated thus:—

To a fresh portion of the solution, add a few drops of a solution of *Red Prussiate of Potash.*

A *Yellow-red* precipitate indicates Mercury.
No precipitate indicates Gold.
No precipitate however also indicates the Perchloride of Mercury.

The discrimination of Perchloride of Mercury from Gold, I shall show you how to effect, when I come to speak of the confirming tests.

Experiment 12.—The *Brown precipitates* produced by potash indicate two metals.

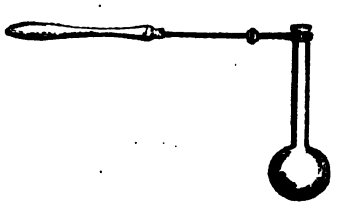
No. 26. Iron, persalts.
27. Silver.

These you discriminate as follows:—

To a fresh portion of the solution, add a few drops of a solution of *Red Prussiate of Potash.*

No precipitate indicates Persalts of Iron.
A *Brown* precipitate indicates Silver.

Thus far we have considered the reactions of the Precipitants which indicate the *metals* or BASES of the salts we are examining. I proceed next to specify the reactions of the Precipitants which indicate their ACIDS.



B.—TESTING FOR ACIDS.

The number of *Indicating Precipitants for Acids* is four. Their names are—

1. Nitrate of Barytes.
2. Nitrate of Silver.
3. Nitrate of Lead.
4. Chloride of Calcium.

These you have already in solution, and you are to apply them in small quantities of 4 or 5 drops at a time, to similar small quantities of the unknown solution contained in separate test glasses, in the same manner as you applied the indicating precipitants for the metals.

The *results* of the testing you will carefully mark down upon the ASSAY NOTE as you proceed.

Experiment 13.—First of all, you take in a test glass a few drops of the unknown solution, and add to it a few drops of the solution of *Nitrate of Barytes.*

You will observe one of three results, to wit—

No Precipitate.
A *White* Precipitate.
A *Yellow* Precipitate.

Experiment 14.—The salts which give *no precipitate* with Nitrate of Barytes, are of six kinds, namely:—

No. 1. Nitrates.
2. Chlorates.
3. Chlorides.
4. Iodides.
5. Arsenites.
6. Sulphides.

To discriminate these from one another, you take a fresh portion of the solution, and test it with the solution of *Nitrate of Silver.*

No precipitate indicates Nitrates and Chlorates.
A *White* precipitate indicates Chlorides.
A *Black* precipitate indicates Sulphides.
Any other precipitate is to be disregarded.

The Indicating Tests can give you no farther information conducive to the discrimination of Nitrates from Chlorates. I shall hereafter show you how to effect this discrimination by means of *confirming tests.*

Experiment 15.—The Iodides and Arsenites are to be discriminated thus:—You test a fresh portion of the solution with a few drops of a solution of *Nitrate of Lead*, and notice the *colour* of the precipitate:—

Yellow indicates Iodides.
White indicates Arsenites.

Experiment 16.—The salts which give a *white precipitate* with Nitrate of Barytes, are of seven kinds, namely:—

No. 7. Fluorides.
8. Phosphates.
9. Arseniates.
10. Borates.
11. Oxalates.
12. Carbonates.
13. Sulphates.

To proceed in the discrimination of these seven classes of salts from one another, you are to mix the solution which contains the white precipitate with a few drops, or not more than its own bulk, of *Nitric Acid*, and to stir up the mixture with a glass rod. This process separates the white precipitates into three classes, to wit:—

Those which *dissolve* in nitric acid *without effervescence*.

Those which *dissolve* in nitric acid *with* effervescence.

Those which *do not dissolve* in nitric acid.

Experiment 17.—The *white precipitates* which are produced by Nitrate of Barytes, and which *dissolve* in nitric acid *without effervescence*, and are accordingly denoted in your ASSAY NOTE—by P white S— indicate five salts, namely:—

Fluorides.	Borates.
Phosphates.	Oxalates.
Arseniates.	

To distinguish these from one another you are to test a fresh portion of the solution with *Nitrate of Silver*.

No precipitate indicates Fluorides.

A *Yellow* precipitate indicates Phosphates.

A *Brown* precipitate indicates Arseniates.

Any other precipitate is to be disregarded.

Experiment 18.—Take in an ounce conical test glass two drops of the unknown solution, and add one drop of the solution of *Chloride of Calcium*. You will see a white precipitate, let whatever will be present. Now by means of the water bottle, page 31, slowly add *distilled water* to the mixture under continual stirring, till the precipitate dissolves, or till the test glass becomes nearly full.

If the precipitate is *soluble*, the salt is a Borate.

If it is *insoluble*, the salt is an Oxalate.

The *white precipitates* which are produced by Nitrate of Barytes, and which *dissolve* in nitric acid *with effervescence*, and are accordingly denoted in your ASSAY NOTE—by P white S eff.—indicate Carbonates.

The *white precipitates* which are produced by Nitrate of Barytes, and which *do not dissolve* in nitric acid, indicate Sulphates.

The *yellow precipitates* which are produced by Nitrate of Barytes indicate

No. 14. Chromates.

Such are the reactions of the indicating tests for acids.

I shall now present you with a synoptical view of these Indicating Tests, arranged in two separate TABLES, one of them showing the precipitants for *Metals*, the other the precipitants for *Acids*.

INDICATING PRECIPITANTS FOR METALS IN SALTS.

Solutions to be Neutral.				Solutions to be Acid.	
Carbonate of Soda.	Ammonia.	Potash.	Red Prussiate of Potash.	Sulphuretted Hydrogen Gas.	METALS Indicated.
None					1 Potassium.
None					2 Sodium.
None					3 Ammonium.
	None				4 Barium.
	None				5 Strontium.
	None				6 Calcium.
		White	Brown		7 Manganese.
		White	Blue		8 Iron, protosalts.
		White — All 5 are insoluble in excess.	None		9 Magnesium.
		White		Yellow	10 Cadmium.
		White		Black	11 Bismuth.
		White	Yellow-red		12 Zinc.
		White	White		13 Tin, protosalts.
		White		None	14 Aluminum.
		White — All 6 are soluble in excess.		Black	15 Lead.
		White		Yellow	16 Tin, persalts.
		White		Orange	17 Antimony.
		Black, See Gold, No. 25.	Red-brown		18 Mercury, its protosalts.
		Blue, If boiled, Red.			19 Cobalt.
		Blue, If boiled, Black.			20 Copper.
		Green	Yellow-green		21 Nickel.
		Green	None		22 Chromium.
		Green	Light Blue		23 Iron, persalts & protosalts mixed.
		Yellow	Yellow-red but none from the Perchloride.		24 Mercury, its persalts.
		Yellow. sometimes slight and black.	None		25 Gold.
		Brown	None		26 Iron, persalts.
		Brown	Brown		27 Silver.

INDICATING PRECIPITANTS FOR ACIDS IN SALTS.					
Nitrate of Barytes.		Nitrate of Silver.	Nitrate of Lead.	Chloride of Calcium.	SALTS Indicated.
None		None			1 Nitrates.
None		None			2 Chlorates.
None		White			3 Chlorides.
None			Yellow		4 Iodides.
None			White		5 Arsenites.
None		Black			6 Sulphides.
White		None			7 Fluorides.
White	All 5 soluble	Yellow			8 Phosphates.
White	in Nitric Acid,	Brown			9 Arseniates.
White	without			White, Sol. in water.	10 Borates.
White	Effervescence.			White, Insol. in water.	11 Oxalates.
White	Soluble in Acids with Effervesc.				12 Carbonates.
White	Insol. in Acids.				13 Sulphates.
Yellow					14 Chromates.

Before proceeding farther, I request you to compare these TABLES with your ASSAY NOTES, and to draw conclusions, from the results of your experiments, in regard to the nature of the substance which you have had to examine.

First, as to the METALS—suppose your ASSAY NOTE to read thus:—

Carbonate of Soda	P.
Ammonia	P.
Potash	P. Brown.
Red Prussiate of Potash . .	P. Brown.
Sulphuretted Hydrogen . .	

The interpretation must be as follows:—

Carbonate of Soda = P., shows that the metal is not one of the three first of those on the list of components given at page 65.

Ammonia = P., shows that the metal is not one of those from No. 4 to No. 6 in that list.

Potash = P. *brown*, shows that the metal is either Iron, No. 26, or Silver, No. 27. See Exp. 12, p. 77.

Red Prussiate of Potash = P. *brown*, shows finally that the metal is *Silver*.

Next, as to the ACIDS—let your ASSAY NOTE read thus:—

Nitrate of Barytes	P. white, sol.
Nitrate of Silver	O.
Nitrate of Lead	
Chloride of Calcium . . .	

Nitrate of Barytes = P. *white, sol.*,—shows the salt to be one of those from No. 7 to No. 11, in the list of salts given at page 65.

Nitrate of Silver = O, shows it to be a *Fluoride*.[1]

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[1] *To Teachers.*—At this point the teacher may either collect the ASSAY NOTES, and revise what has been done, or he may go on with the Confirming Tests, and leave the ASSAY NOTES with the pupils, until the testing is entirely finished.

The manner of teaching the methods of applying the Confirming Tests must be regulated by the number of persons to be taught, and the quantity of time and apparatus at command. All the students may go through the whole series of experiments, or each of them may be instructed to perform only those particular experiments which relate to the Metal and Acid indicated by his ASSAY NOTE.

But, indeed, a student can scarcely have a better set of elementary experiments, than that which consists in trying the action of Tests with all the salts at his command, so as to make himself acquainted with the *colours*, consistence, changeableness, &c., of the various precipitates which characterise different kinds of salts.

CONFIRMING TESTS.

WHEN you have applied the set of Indicating Tests, and imagine that you have detected both the base and the acid of your salt, it is proper to make use of the *Confirming* Tests, in order to convince yourself that there is no mistake.

These tests also are unavoidably necessary whenever you have to do with a nitrate, a chlorate, an alcali, or an alcaline earth—all of which compounds are left undiscriminated by the Indicating Tests which we have employed.

To guard against the possibility of error, the rule is good, to test the unknown substance, or its solution in water, with as many different precipitants, or by as many different experiments as you can conveniently employ—paying especial attention to the action of such tests as serve to distinguish the particular elements of your compound from such other elements as most nearly resemble them.

The set of Confirming Tests that I am about to give you, applies only to simple soluble salts, not to mixtures of salts, nor to impure salts, nor to salts that are insoluble in water, or that contain other metals or acids than those that were enumerated at the beginning of these Instructions (page 65).

Finally, these Confirming Tests presuppose the use of the Indicating Tests. They are consequently *Confirming* only when taken in conjunction with the reactions of the *Indicating* Tests. The reason of this is, that *all* the characteristics necessary to fix the identity of the different acids and bases are, for the sake of brevity, not brought into this section; but only so many as are necessary to accomplish the particular end in view, namely, that of discriminating the substances contained in the limiting Table given at the beginning of these Instructions. (See page 65).

Consequently, you are always to begin an analysis with the Indicating Tests, and conclude it with the Confirming Tests.

APPARATUS FOR CONFIRMING TESTS.

THE apparatus here cited is required for performing the Confirming Tests of this section. It is not necessary in teaching a CLASS, to supply each student with a complete set of this apparatus, because the same substances need not be given to all the students at the same time. Each set of apparatus for the Confirming Tests may suffice for four or six pupils.

Porcelain cup 1 inch diameter.
Round Retort Stand, with 1 ring and 1 triangle.
Blowpipe.
Blowpipe Lamp on support.
2 Platinum Blowpipe wires.
2 Slips of Platinum foil for the Blowpipe.
Platinum pointed tongs, fig. 60.
Thin Copper wire for Blowpipe Experiments.
Box of Oxidating Pastiles.
Box of Reducing Pastiles.
3 Wires for holding Blowpipe Pastiles.
Hammer.
Steel Anvil.
3 Tubes for sublimations, hard glass, 2 inches by ¼ inch.
Box of Books of Test papers.
Support to show sublimates before the blowpipe.
Blowpipe Fluxes in boxes:—
Borax.
Carbonate of Soda.
Microcosmic Salt.
Bottle for solution of Cobalt, with pipette or long stopper.

Bottles for Reagents in solution, 2 oz. size, with stoppers, containing:—
Yellow Chromate of Potash.
Red Chromate of Potash.
Yellow Prussiate of Potash.
Sulphate of Lime.
Antimoniate of Potash.
Molybdate of Ammonia.
Sulphuric Acid, concentrated.
Muriatic Acid.

Bottles with wide mouths, to contain the following dry Tests, 1 ounce size:—
Protosulphate of Iron, cryst.
Peroxide of Manganese.
Protochloride of Tin, cryst.
Sulphate of Copper, cryst.
Acetate of Lead, cryst.
Sulphate of Magnesia, cryst.
Chloride of Sodium, cryst.
The following Tests are only required occasionally. It will be sufficient if 1 bottle of each is in the Laboratory.
Chloride of Platinum.
Chloride of Gold.

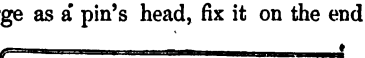
A.—CONFIRMING TESTS FOR METALS.

POTASSIUM, SODIUM, AMMONIUM.—See Experiments, 1, page 71.

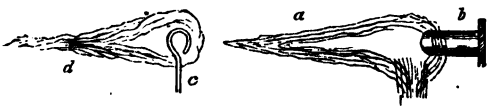
56.

1. Take a porcelain cup of this size. Mix in it a test spoonful of the dry salt, with a test spoonful of carbonate of soda, and a few drops of water. Support it over a spirit lamp and apply heat. If the *odour of Ammonia* is produced, the salt contains *Ammonium*.

2. Take a bit of the salt as large as a pin's head, fix it on the end of a platinum blowpipe wire, of this size, and hold it in a small blue flame produced by a re-


57.

duced gas or spirit lamp flame, or else hold it before the blowpipe oxidating flame in this manner:—



58.

If a *strong yellow flame* is formed round the assay, *c*, *d*, the salt contains *Sodium*. If a *violet* colour or *no* colour is given to the flame, the salt contains *Potassium*.

You will observe that I suppose, throughout, that the salts under analysis are in a state of purity. The tests which I direct to be applied are not qualified to act upon *mixtures* of salts in the same manner as upon *simple* salts. Thus, for example, if a salt of *Potassium* is mixed with a salt of *Sodium*, the mixture submitted to the last experiment, gives only the character of *Sodium*, even if the mixture contains three hundred parts of Potassium to one part of Sodium. The person, therefore, who provides you with the *salts that are to be analysed*, and with the *tests that are to be applied to them*, must guard against any source of error of that description.

But since the presence of Sodium in salts of potassium is very common and very difficult to avoid, it is proper to apply the following *direct* tests for Potassium, in every analysis you make of an alcaline salt, whether it gives the yellow flame of soda or not.

3. Add to a concentrated solution of the salt, a drop of a solution of CHLORIDE of PLATINUM in spirit of wine.

A *yellow* precipitate indicates *Potassium*.

No precipitate indicates *Sodium*.

59.

4. Add to a concentrated solution of the salt, which must not have any free acid, a few drops of a concentrated solution of ANTIMONIATE of POTASH.

No precipitate indicates *Potassium*.

A white crystalline precipitate slowly formed indicates *Sodium*.

BARIUM, STRONTIUM, CALCIUM. — See Experiment 2, page 72, where the salts of Barytes, Strontian, and Lime, are distinguished from those of Potash, Soda, and Ammonia, by means of a solution of carbonate of soda. They may also be distinguished from the same salts by DILUTED SULPHURIC ACID, which gives a *white precipitate* with these Earths, but not with the Alcalies.

These three metals are most readily discriminated from one another by the conjoint action of solutions of YELLOW CHROMATE OF POTASH and BICHROMATE OF POTASH.

5. To a few drops of the concentrated solution of the unknown salt, add a few drops of a solution of BICHROMATE OF POTASH.

If you get a *precipitate*, the metal is *Barium.*

If you get no precipitate, test another portion of the concentrated solution of the unknown salt with a few drops of a solution of YELLOW CHROMATE OF POTASH.

If you get a *precipitate*, the metal is *Strontium.*

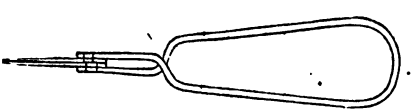
If you get *no* precipitate, the metal is *Calcium.*

ACTION of the two Chromates of Potash, with concentrated solutions of the Alcaline Earths.

Metals under Examination.	Bichromate of Potash.	Yellow Chromate of Potash.
Barium.	Precip.	Precip.
Strontium.	o	Precip.
Calcium.	o	o

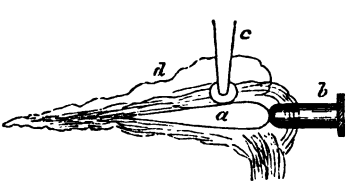
These reactions do not, however, take place with distinctness in *dilute* solutions of these metals.

6. Take a bit of the solid salt in the platinum blowpipe tongs, moisten it with water, and dip it into the upper part of the blowpipe flame, in



60.

this manner, fig. 61, where *c* represents the points of the tongs, and *b* the point of the blowpipe:—



61.

If it gives a pale *green* colour to the upper part of the flame, as at *d*, it is *Barium.*

If it gives a *red* colour to the flame, it is *Strontium* or *Calcium.*

The last two metals are distinguished as follows :—

7. To a solution of the salt, add a solution of SULPHATE OF LIME, prepared by boiling precipitated Sulphate of Lime in water.

If it gives a precipitate, the metal is *Strontium*.

If not, the metal is *Calcium*.

MANGANESE.—See Experiment 4, page 74.

8. Take a platinum blowpipe foil, mix on it a bit of the dry salt with a test spoonful of dry CARBONATE OF SODA, and fuse the mixture before the blowpipe. The melted mass acquires a *green* colour.

9. Make a bead of Borax on the platinum wire before the blowpipe, and melt in it a little of the dry salt. Use the outer blowpipe flame. See Experiment 31, page 90. The bead acquires an *amethyst colour*.

IRON.—See Experiments 4, 10, and 12, pages 74, 76, and 77.

10. Add a few drops of a solution of YELLOW PRUSSIATE OF POTASH to a solution that contains a *salt of iron*.

A *white* precipitate indicates a *Protosalt* of Iron.

A *dark-blue* precipitate indicates a *Persalt* of Iron.

A *pale-blue* precipitate indicates a mixture of the two species.

11. Expose a solution of a *Protosalt of Iron* to an atmosphere of SULPHURETTED HYDROGEN GAS, See Experiment 5, page 75. It gives *no precipitate*.

12. Add to the solution of the Protosalt of Iron as much AMMONIA as gives it a strong smell of Ammonia, and again expose it to the atmosphere of SULPHURETTED HYDROGEN GAS. A *black* precipitate is produced.

13. Treat in the same manner a solution of a *Persalt* of Iron. Without *Ammonia*, it gives a *white* precipitate; and *with* Ammonia, a *black* precipitate.

MAGNESIUM.—See Experiment 4, page 74.

ALUMINUM.—See Experiment 7, page 75.

ZINC.—See Experiment 6, page 75.

14. Mix a test spoonful of the salt with a little water, spread it on charcoal in a flat cake of this size, and ignite it before the blowpipe. Then moisten the ignited salt with a drop of a strong solution of nitrate of cobalt, and again heat it before the blowpipe to redness. When it is cold, examine the change of colour produced :— 62.

A salt which acquires a *flesh-red colour* from this treatment contains *Magnesium*.

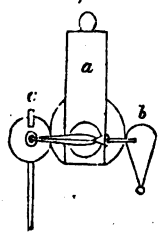
If its colour is *blue*, the salt contains *Aluminum*.

If it is *green*, the salt contains *Zinc*.

These colours are best examined by daylight.

CADMIUM.—See Experiment 5, page 75.

15. Mix half a test spoonful of the salt with as much dry CARBONATE OF SODA, and heat it on charcoal in the inner (reducing) flame of the blowpipe.



63.

A *brown powder* will appear round the assay, upon the charcoal.

[The figure shows the method of exposing a substance on charcoal to the flame of the blowpipe; *a* is the blowpipe lamp, *b* the blowpipe, *c* the assay upon a round disc of charcoal held by a bent slip of tin-plate.]

BISMUTH.—See Experiment 5, page 75.

16. Treat the salt in the same way as the salt of Cadmium, in Experiment 15.

A *yellow powder* is perceived on the charcoal, with a metallic bead in the centre of it.

Wrap the bead of metal in paper and give it a stroke with a hammer. You will find it to be *brittle*. See Experiment 19, below.

ZINC.—See Experiment 6, page 75.

17. I spoke of this metal in connection with Magnesium, Exper. 14. With SULPHURETTED HYDROGEN, zinc gives a *White* precipitate.

TIN.—See Experiments 6 and 7, page 75.

18. Mix a solution of a *Protosalt of Tin* with a few drops of a solution of CHLORIDE OF GOLD. A *purple* precipitate appears.

19. Mix a small bit, not larger than a pin's head, of a dry salt of tin, either containing the *protoxide* or the *peroxide*, with a test spoonful of dry CARBONATE OF SODA, and half that quantity of BORAX. Place the mixture on charcoal, and heat it strongly and for some time in the inner blowpipe flame, till the metal of the salt is reduced. See Experiment 31, page 90.

You will obtain a bright white metallic bead, which *flattens* when struck with the hammer. The malleability of beads of this metal, distinguishes them from beads of *Bismuth* produced in similar experiments. (Exp. 16.) Their brilliancy distinguishes them from *Lead*.

ALUMINUM.—See Experiment 7, page 75.

20. I spoke of this metal in connection with Magnesium. See Experiment 14.

Add to the solution of the salt of alumina a small quantity of solution of CAUSTIC POTASH, or CARBONATE of POTASH, and then SULPHURIC ACID in slight excess, so that the mixture will redden blue litmus paper. After some delay, *crystals of alum* will be produced in the mixture.

LEAD.—See Experiment 7, page 75.

21. Mix half a test spoonful of the dry salt with a test spoonful of

dry CARBONATE OF SODA, place the mixture on charcoal and heat it in the inner blowpipe flame, till the metal is reduced.

You will obtain beads of METALLIC LEAD, and the charcoal acquires a coating of *yellow powder*.

These beads differ from those of *Tin* by being convertible into a volatile oxide, and from those of *Bismuth* by being *malleable* and not brittle.

22. Mix a drop of a solution of lead with a test glass full of water, and add a few drops of SULPHURIC ACID.

You will obtain a *white precipitate*.

ANTIMONY.—See Experiment 7, page 75.

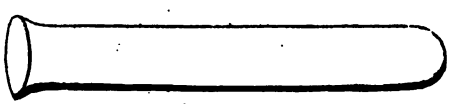
23. Mix half a test spoonful of the dry salt with a test spoonful of dry CARBONATE OF SODA, and ignite the mixture on charcoal in the inner blowpipe flame till the metal is reduced.

You will obtain *globules of metal* from which a thick white smoke will rise.

If a melted bead of antimony is thrown on the ground, it divides into several globules which produce a thick white smoke (oxide of antimony).

MERCURY.—See Experiment 8, page 76.

24. Mix half a test spoonful of the dry salt with a test spoonful of dry CARBONATE OF SODA. Put the mixture into a little glass tube, and heat it over the spirit lamp.



64.

You will soon see *metallic mercury* condensed upon the upper part of the tube.

25. Mix a solution of a salt of Mercury with a few drops of AMMONIA.

A *black* precipitate indicates a *Protosalt* of Mercury.

A *white* precipitate indicates a *Persalt* of Mercury.

COBALT.—See Experiment 9, page 76.

26. Make a glass bead with borax on a platinum wire before the blowpipe. To this add a bit of the salt of cobalt, much smaller than a pin's head, and melt it into the bead.

The glass acquires a dark-blue colour, both in the outer and inner flame.

27. Mix a few drops of a solution of cobalt with a solution of RED PRUSSIATE OF POTASH.

You get a *brownish-red* precipitate.

COPPER.—See Experiment 9, page 76.

28. Mix a few drops of a solution of copper with a solution of RED PRUSSIATE OF POTASH.

The precipitate is *yellowish-green.*

29. Mix the solution of copper with a *very small* quantity of AMMONIA.

You get a *greenish* precipitate, which dissolves in a larger quantity of ammonia, and produces a splendid blue solution.

30. Mix the solution of Copper with a solution of YELLOW PRUSSIATE OF POTASH.

The precipitate is *reddish-brown.*

31. Melt a small quantity of the dry salt in a borax bead before the blowpipe.

In the *outer* flame, it gives a *transparent-green* glass.[1]

In the *inner* flame, it gives an *opaque-brown* glass.[2]

NICKEL.—See Experiment 10, page 76.

32. Mix the solution of Nickel with a *very small* quantity of AMMONIA.

You get a *greenish* precipitate, which dissolves in a larger quantity of Ammonia, and gives a *violet* coloured solution.

33. Mix the solution of Nickel with a solution of YELLOW PRUSSIATE OF POTASH.

The precipitate is *pale green.*

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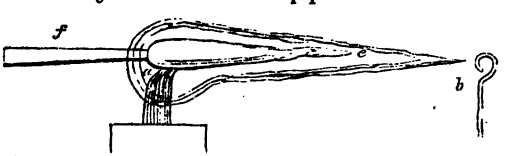
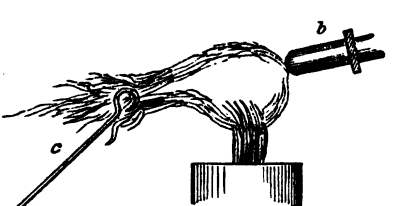
[1] The following figure shows the method of exposing a substance to the *outer* or *oxidating* flame of the blowpipe.



65.

[2] The following figure exhibits a bead exposed to the *inner* or *reducing* blowpipe flame.



66.

CHROMIUM.—See Experiment 10, page 76.

34. Melt a little of the dry salt of oxide of Chromium in a borax bead before the blowpipe.

It gives a *transparent-green glass*, both in the inner flame and outer flame.

35. Mix the solution of oxide of Chromium with a few drops of AMMONIA.

The colour of the precipitate is *grey*, by candle-light *violet*.

36. Mix the solution of oxide of Chromium with YELLOW PRUSSIATE OF POTASH.

There is no precipitate.

GOLD.—See Experiments 8 and 11, pages 76, 77.

37. Mix the solution of Gold with a solution of PROTOSULPHATE OF IRON.

A *dark-brown* precipitate of metallic gold is produced.

38. Mix the solution of Gold with a solution of YELLOW PRUSSIATE OF POTASH.

The solution acquires an *emerald-green colour*.

39. Mix the solution of Gold with a solution of PROTOCHLORIDE OF TIN.

A *purple* precipitate is produced.

SILVER.—See Experiment 12, page 77.

40. Mix a diluted solution of Silver, with a few drops of MURIATIC ACID, or of a solution of ANY CHLORIDE.

You will get a *white precipitate*.

If you add AMMONIA to the mixture the precipitate dissolves.

If you add NITRIC ACID to the mixture the precipitate remains undissolved.

41. Mix the dry salt of Silver with dry CARBONATE OF SODA, and ignite the mixture on charcoal before the blowpipe.

Bright metallic silver appears on the charcoal.

B.—CONFIRMING TESTS FOR ACIDS.

NITRATES.—See Experiment 14, page 78.

42. Take a porcelain cup, and a test spoonful of the Nitrate. Prepare a solution. Add a few drops of sulphuric acid. Place a crystal of green sulphate of iron in the middle of the solution. Support the cup over the spirit lamp, and apply heat. You will see a dark-brown colour produced near the crystals. Shake the cup. The brown colour spreads through the whole liquor.

67.

43. Mix the dry Nitrate with dry Bisulphate of Potash, a test spoonful of each. Put the mixture into a large test tube, and heat it over the spirit lamp.

You will observe the tube to be filled with *dark-yellow gas*. This experiment serves to distinguish Nitrates from Chlorates.

44. Put the dry Nitrate into a large test tube. Add Muriatic Acid. Apply heat.

White vapours of Nitric Acid are expelled. They redden litmus paper.

CHLORATES.—See Experiment 14, page 78.

45. Put a very small quantity of the dry Chlorate into a large test tube. Add Muriatic Acid. Apply heat.

A *yellowish-green gas* is expelled, having a very pungent odour.

46. Take a small test tube. Put into it a test spoonful of the dry Chlorate. Apply heat. The salt melts and oxygen gas soon after issues from the tube. Inflame a bit of wood. Blow out the light, and hold the glimmering match to the mouth of the tube. The oxygen gas re-illumes the match. This experiment does not distinguish Chlorates from Nitrates.

47. Take a bit of thin copper wire. Make a coil at the end of it, and melt into the coil a crystal of microcosmic salt. Hold the coil over a small flame till the salt ceases to effervesce, and the wire becomes red hot. Now press the hot bead upon a bit of the dry Chlorate, not larger than a pin's head. Reduce the flame of your lamp as low as you can without extinguishing it—so low as to leave only a small blue flame. Hold the coil with the Chlorate upon it, so that it shall just touch the top of the reduced flame. Thereupon a *bright blue flame* surrounds the subject of experiment. This experiment completely distinguishes Chlorates from Nitrates.

68.

All substances that contain CHLORINE give this *blue flame*, and all substances that contain IODINE, treated in the same way, give a splendid *green flame*.

CHLORIDES.—See Experiment 14, page 78.

I have spoken already, Experiment 40, of the detection of Silver by solutions of CHLORIDES. The operation of detecting Chlorides by solutions of SILVER is the same.

The method of detecting Chlorine by means of microcosmic salt and a copper wire, explained already, in treating of CHLORATES, Experiment 47, is equally applicable to CHLORIDES.

48. Mix the dry salt with concentrated Sulphuric Acid in a large test tube, and apply heat.

White vapours of Muriatic Acid are formed. Hold a glass rod

moistened with Ammonia at the mouth of the tube. A thick *white smoke* is produced.

49. Take a test tube. Mix in it a test spoonful of the dry salt with a few drops of concentrated Sulphuric Acid and a test spoonful of *Peroxide of Manganese.* Apply heat.

In this case *Chlorine gas* is disengaged. It has a green colour and suffocating odour.

IODIDES.—See Experiment 15, page 78.

50. Take a large test tube. Put into it a test spoonful of the dry salt mixed with an equal quantity of dry BISULPHATE OF POTASH. Apply Heat.

You will see *Violet Vapours* of Iodine in the tube.

The method of detecting IODINE by means of a copper wire, I have explained in speaking of the CHLORATES, Exp. 47.

51. Mix a few drops of the Solution of the Iodide with a few drops of NITRIC ACID, and add a small quantity of STARCH PASTE prepared with hot water, or else use a test paper impregnated with starch.

A *blue colour* is produced. The paper turns *blue.*

52. Pour the Solution of the Iodide in which the Indicating Test, NITRATE OF LEAD, Experiment 15, page 78, has formed a yellow precipitate, into a test tube, and boil it with the precipitate.

When the solution cools, brilliant flat golden-yellow crystals appear in it.

ARSENITES.—See Experiment 15, page 78.

53. Mix the solution of the Arsenite with a solution of SULPHATE OF COPPER.

A *Green Precipitate* is produced.

54. Mix the solution of the Arsenite with a solution of NITRATE OF SILVER, and a very small quantity of AMMONIA.

A *yellow precipitate* is produced.

55. Mix the solution of the Arsenite with a drop or two of Muriatic acid, and expose the mixture to an atmosphere of SULPHURETTED HYDROGEN GAS (See Experiment 5, page 75).

A *yellow precipitate* is produced.

56. Mix half a test spoonful of the dry salt with a test spoonful of dry CARBONATE OF SODA. Heat the mixture on Charcoal in the inner blowpipe flame. After a short ignition, hold the charcoal under your nose. You will perceive *the odour of garlic*, by which metallic arsenic is specially characterised. Be cautious in smelling the vapour of arsenic, as it is poisonous.

SULPHIDES.—See Experiment 14, page 78.

57. Take a test tube. Mix in it a test spoonful of the dry Sulphide with a little *Muriatic Acid.* Apply Heat.

Effervescence is produced, and the odour of *Sulphuretted Hydrogen Gas* is perceived. A bit of white paper moistened with a solution of Lead, and held at the mouth of the tube, turns *black*.

58. Heat a test spoonful of the dry Sulphide on charcoal before the blowpipe.

The odour of SULPHUROUS ACID GAS will be perceived.

FLUORIDES.—See Experiment 17, page 79.

59. Take a small test tube. Mix in it the Fluoride with dry BISULPHATE OF POTASH, a test spoonful of each. Put a slip of moistened Brazil wood test paper into the upper end of the tube. Apply Heat.

Hydrofluoric acid will be disengaged by the mixture, and will *corrode* the inside of the tube; and change the red colour of the Brazil test paper to *yellow*.

Wash and dry the tube to render the corrosion visible.

PHOSPHATES.—See Experiment 17, page 79.

60. Precipitate a few drops of the solution of the Phosphate with a solution of ACETATE OF LEAD. Collect the white precipitate upon a filter. Wash it. Dry it. Place it upon Charcoal and melt it in the outer flame of the blowpipe.

When the bead cools, it will be of a dark colour, opaque, and *crystallised into numerous facets*. By this character the Phosphates are distinguished from the Arseniates. See Experiment 63, page 95.

61. Mix a solution of the Phosphate with a solution of SULPHATE OF MAGNESIA, and add AMMONIA.

You will get a *white precipitate*.

62. Add to a solution of MOLYBDATE OF AMMONIA as much Nitric Acid as will redissolve the precipitate which it first produces. Then add an extremely small quantity of the solution of the Phosphate, and *boil the mixture*. The operation should be performed in a test tube.

You will obtain a *yellow precipitate*.

This is the most delicate and certain test for phosphoric acid. No other acid, not even Arsenic acid, which resembles phosphoric acid in so many other particulars, can produce this yellow precipitate in an acidified solution of Molybdate of Ammonia.

ARSENIATES.—See Experiment 17, page 79.

In speaking of the *Arsenites*, I have shown in what manner the *Arsenic* which they contain can be detected before the blowpipe (see Experiment 56, page 93). The same experiment answers also with the Arseniates.

The differences between the Arsenites and Arseniates is best shown by the Indicating Tests, NITRATE OF BARYTES, Experiment 14, page 78, and NITRATE OF SILVER, Experiment 17, page 79.

The difference between the Arseniates and Phosphates, which agree in many respects, is shown by the Indicating Test, NITRATE OF SILVER, Experiment 17, page 79, and by the experiment just described, with MOLYBDATE OF AMMONIA, No. 61.

It is also exhibited in an experiment which I shall now give you.

63. Precipitate a solution of the Arseniate by a solution of ACETATE OF LEAD. Collect the white precipitate on a filter. Wash it. Dry it. Ignite it on charcoal, in the outer flame of the blowpipe.

When the bead cools, it will not be found crystallised into facets, as is the case with the precipitated *phosphate* of Lead.

64. Again, heat the fused bead of *Arseniate* of Lead in the *inner* flame of the blowpipe.

You will perceive a thick smoke which you will find to possess the odour of Arsenic, and you will get beads of metallic lead. These effects are not produced by *phosphate* of lead.

BORATES.—See Experiment 18, page 79.

65. Take a large test tube. Mix in it a concentrated solution of the Borate, with some SULPHURIC ACID. Boil the mixture, and let it cool.

You will perceive flat shining crystals of Boracic Acid.

66. Pour off the liquid. Wash the crystals from sulphuric acid with a little cold water. Repeat the washing several times. Then boil the crystals with water in a test tube. Test the solution with Litmus paper and Turmeric paper.

The blue litmus is turned *Red.*

The yellow turmeric is turned *Brown.*

67. Take a porcelain cup. Mix the solution of the Boracic Acid, or else a test spoonful of the solid Borate moistened with sulphuric acid, with a few drops of alcohol. Inflame the mixture.

You will see a *green flame.*

OXALATES.—See Experiment 18, page 79.

68. Take a large test tube. Put into it three test spoonfuls of the dry oxalate. Add a few drops of concentrated sulphuric acid. Apply a moderate heat.

Effervescence takes place. The gas that escapes is a mixture of carbonic acid and carbonic oxide.

Apply a light to the mouth of the tube. The carbonic oxide *burns with a blue flame.*

69. Mix the solution of the oxalate with a solution of SULPHATE OF LIME.

You will get a *white precipitate.*

CARBONATES.—See page 79.

70. Mix the dry Carbonate with a little water. Add a few drops of MURIATIC ACID.

Effervescence takes place. The gas that escapes is *without odour.*

SULPHATES.—See page 79.

71. Mix a test spoonful of the dry sulphate with as much dry carbonate of soda. Place it on charcoal, and heat it in the inner flame of the blowpipe. Lay the fused mass on a piece of bright silver, and add to it a drop of water. After a minute's repose, wash the mixture from the silver.

You will perceive a *black mark* on the silver.

This experiment distinguishes the SULPHATES from all other salts in our list except the SULPHIDES, from which they are distinguished by Experiment 57.

CHROMATES.—See page 79.

72. Take a large test tube. Mix in it a test spoonful of the dry Chromate, with the same quantity of CHLORIDE OF SODIUM, and a few drops of concentrated SULPHURIC ACID. Apply heat.

Effervescence takes place, and the tube becomes filled with a *splendid red gas.*

73. Take a large test tube.[1] Mix in it a test spoonful of the Chromate, with a few drops of muriatic acid, and a few drops of alcohol, and boil the mixture over the spirit lamp.

The boiling liquor gives off muriatic ether, and the colour of it becomes *green.*

74. Before the *blowpipe*, the salts of chromic acid give the same results as the salts of oxide of chromium. See Experiment 34, page 90.

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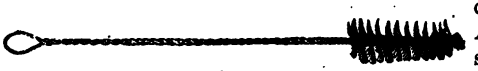
[1] Test tubes have been frequently directed to be used in the preceding experiments. As in such experiments scrupulous cleanliness is required, I may add a few words respecting the mode of cleaning such tubes. After each experiment they should be filled with water, before the products of the experiment have dried upon the surface. If the matters adhere, they may be removed by the use of a brush resembling fig. 69. Waste solutions of acids, alcalies, and alcohol, are used in cleaning glass vessels.



69.

To Teachers.—Where Chemistry is taught only in Lectures, because no conveniences exist for teaching Practical Chemistry, it is an excellent practice for the teacher to give his pupils specimens of salts, such as are enumerated at page 67, to be analysed at their own houses. This method is practised at the German Universities with much success. The students apply themselves to these minute analyses with great zeal, and rapidly acquire considerable analytical skill.

ON THE PERFORMANCE OF ANALYTICAL EXPERIMENTS BY MEANS OF EQUIVALENT TEST LIQUORS.

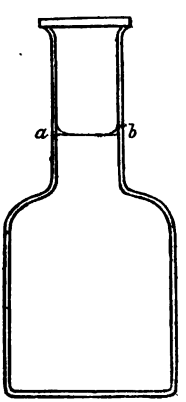
CHEMICAL substances act upon one another in quantities that are represented by their atomic weights. I have explained that subject fully in a former section, on the atomic theory. The weights given in the table at page 22, state a quantity of each substance; which, when weighed in English grains, constitute what I call a *Test atom*. Thus, 664·7 grains is the test atom of anhydrous carbonate of soda; and 500·8 grains is the test atom of anhydrous sulphuric acid.

When a test atom of any substance is dissolved in water, and the solution is farther diluted with water till it occupies the bulk of a decigallon, at the temperature of 62° F., I call that a *solution of one hundred degrees of strength*, and I mark it 100°. Hence, a solution of *carbonate of soda of* 100° contains 664·7 grains of that salt in a decigallon of solution. *Sulphuric acid of* 100° contains 500·8 grains of the anhydrous acid in a decigallon of the diluted acid. If *two test atoms* of the dry test are contained in the same bulk of solution, I call its strength 200°, &c. It is evident from this, that equal measures of solutions of the same degree are equivalent in chemical power to each other, and that any quantity by weight of a test can be taken by measuring off a corresponding quantity of its solution.

APPARATUS FOR CENTIGRADE TESTING.

For operating in this way it is necessary to be provided with graduated glass instruments such as I shall now describe.

The bottle fig. 71 in the margin contains, when filled up to a mark on the neck, 1 decigallon, or 1000 septems, or $\frac{1}{10}$ gallon, of any liquor.



71.

To prevent any misconception as to the relations and capacities of the DECIMAL MEASURES employed in Centigrade Testing, I must call the reader's attention to the Tables of Imperial Liquid Measures presented in page 98. The upper table shows the measures that are established by Act of Parliament. The lower table explains the decimal system, which I recommend for chemical use.

IMPERIAL LIQUID MEASURE.

CORRESPONDENCE OF THE WEIGHT AND MEASURE OF WATER.
Temperature 62° F. Barom., 30 inches. Weight, Avoirdupois.

Gallon.	Quarts.	Pints.	Pounds.	Fluid Ounces.	Cubic Inches.	Fluid Drachms.	Grains.
1	4	8	10	160	277·274	1280	70000
	1	2	2·5	40	69·3185	320	17500
		1	1·25	20	34·6593	160	8750
$\frac{1}{10}$			1	16	27·7274	128	7000
$\frac{1}{70}$			$\frac{1}{7}$	2·286	3·96106	18·286	1000
$\frac{1}{160}$			$\frac{1}{13}$	1·6	2·77274	12·8	700
				1	1·73296	8	437·5
				·5770	1·0	4·6164	252·458
				·2286	·396106	1·8286	100
				·2083	·361033	1·6667	91·1458
$\frac{1}{1000}$			$\frac{1}{160}$	·16	·277274	1·28	70
				·125	·216620	1·0	54·6875
$\frac{1}{10000}$			$\frac{1}{1000}$	·016	·027727	·128	7
				·0023	·003961	·01829	1

The figures that have a dot over them are inexact.

IMPERIAL LIQUID MEASURE.

DIVIDED DECIMALLY.

Gallon.	Deci-Gallons.	Centi-Gallons.	Milli-Gallons.	Septems.	Avoirdupois Weight of Water at 62° F.	
					Grains.	Pounds.
1.	10·	100·	1000·	10000·	70000·	10·
·1	1·	10·	100·	1000·	7000·	1·
·01	·1	1·	10·	100·	700·	·1
·001	·01	·1	1·	10·	70·	·01
·0001	·001	·01	·1	1·	7·	·001

1 Quart = 2500 Septems. 1 Fluid Ounce = 62·5 Septems.
1 Pint = 1250 Septems. 1 Cubic Inch = 36·06543 Septems.
1 Centimetre Cube = 2·2 Septems. 1 Litre = 2·2 Decigallons.

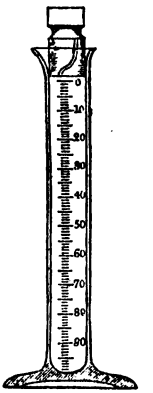
The unit of this system of decimal measures, is called a SEPTEM, because it contains 7 grains of pure water at the Parliamentary Standard.

100 Septems = $\frac{1}{10}$ lb. of water = $\frac{1}{100}$ gallon.
1000 Septems = 1 lb. of water = $\frac{1}{10}$ gallon.
10,000 Septems = 10 lbs. of water = 1 gallon.

I give the name of DECIGALLON to the measure that contains 1 lb. of water, or the tenth part of the Imperial Gallon.

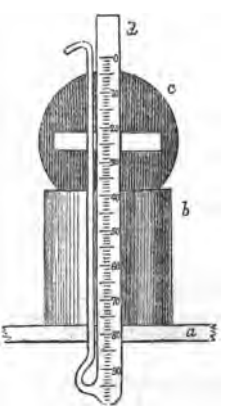
The table itself explains all other relations.

Fig. 72, represents a CENTIGRADE TEST TUBE, more commonly called an *Alcalimeter*. It is a narrow glass jar, with a grooved stopper, by using which the contents can be poured out very slowly. It is graduated into a hundred equal parts, each part containing a septem, and the whole 100 parts being equal to a centigallon, or the tenth part of a decigallon.

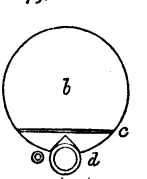


72.

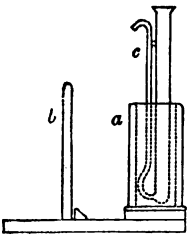
This particular *form* of the centigrade test tube is not essential, and it may therefore be proper to add an account of one or two other varieties of that instrument. Fig. 73 *d* in the margin represents the Pouret or Burette invented by M. Gay Lussac. This is a very convenient and delicate instrument, but rather fragile. It is, in consequence, less suited for common workmen, than the instrument represented by fig. 72, but it gives more precise results. I have added two or three little conveniences to the pouret, which I shall describe. *b*, Fig. 74 is a cylindrical block of wood, the ends of which are cut at right angles with the sides. In the front is a vertical groove. When the block is placed on a horizontal table, *a*, Fig. 73, and the tube is pressed against the groove, the tube is placed at once in a perfectly vertical position, necessary for the accurate observation of the height of the liquor contained within it. *c* is a japanned tin plate, with a horizontal opening covered with white tissue paper. When the surface of the liquor in the pouret is placed against this narrow screen, the height of the liquor can be observed with exactness. The *lower part of the curve formed by the surface of the liquor is taken in all cases as the true level*, and this is well defined, when looked at before the screen.



73.



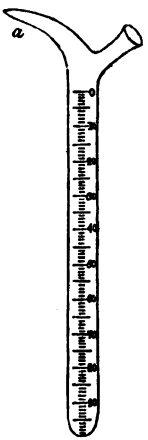
74.



75.

As the pouret is round at the bottom, it requires a separate foot to support it when filled with test liquor. This foot is shown in the margin. *c* is the pouret; *a* is a wooden pillar perforated by an oval hole that supports the pouret in an upright position. When the pouret has been washed, it can be inverted on the peg *b* to drain.

The centigrade tube represented by fig. 76, in the margin is equally simple and delicate. It was suggested by Mr. Binks. The tube can be fixed in a vertical position by the levelling block described above, and be supported by a mahogany foot of the candlestick form.



76.

In using these alcalimeters, they should be held close to the upper end, and when the one with a stopper, fig. 72, is used, the forefinger should be firmly pressed upon the stopper, to keep it in its place. The spout of the alcalimeter must be always greased with a mixture of tallow and wax, to hinder the test liquor from running down the outside of the tube. The tallow is best applied by means of a wooden syringe called a tallow-holder, represented by fig. 77. The mixture of wax and tallow is melted in a porcelain cup and poured warm into the holder, from which it is forced out by the piston as required. In applying the tallow to the beak of the pipette, it should be rubbed on pretty freely, and a small round hole should be pierced through the tallow with a needle. This hole regulates to some extent the force of the stream given by the alcalimeter.

77.

Another form of alcalimeter has recently been invented by Dr. Mohr of Coblentz, which, for most purposes, especially for the analysis of acids and alcalies, in chemical manufactories, is more useful than any of the above forms. It consists of a straight graduated glass tube, *a*, fig. 78, open at both ends, and fixed vertically to a support with two branches, *b*, *b*, *b*. A small glass jet, *c*, is appended to the lower end, by means of a caoutchouc connector, across which a peculiar wire stopcock, *d*, acts. When the stopcock is untouched, the test liquor remains quiet in the tube. When the stopcock is pressed, the liquor descends in a stream, or in single drops, as may be required. When the action is completed, the quantity of test liquor expended is indicated by the centigrade scale, engraved on the tube between *e* and *f*; zero being made at *e*, and 100° at *f*.

Whatever the *form* of the alcalimeter, it must be divided into at

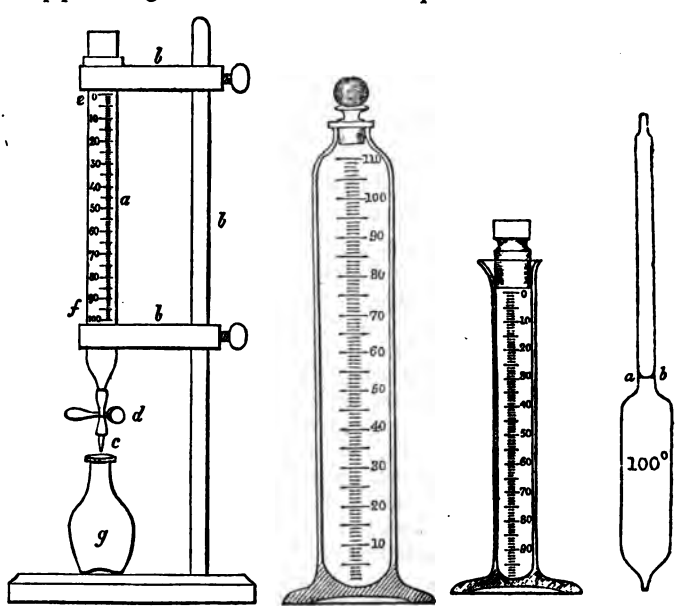
least 100 measures, each containing a septem. In general it is better to have a few more than 100 measures, but a smaller number is not convenient, except for special purposes.

I proceed to notice some other useful instruments.

TEST-MIXER.—Fig. 79 is a *Test-Mixer*, a tall narrow bottle, graduated into a hundred equal parts, and figured from below upwards. The capacity of it may be one, two, or five decigallons, according to the quantity of test liquor that may be required. For small operations, a test-mixer of one decigallon is sufficient. It must be well stoppered and have a broad foot, that it may stand steadily.

Very frequently a test-mixer of the form of fig. 80 is useful. It may contain 100, 200, or 250 septems, and must be graduated into 100 divisions, numbered from below upwards, so as to have zero (0°) of the scale at the bottom. In the figure, the graduation is numbered the wrong way. This instrument serves to prepare test solutions of graduated strength for analytical operations of every description.

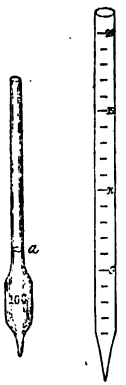
PIPETTES TO DELIVER FIXED QUANTITIES OF TEST LIQUORS.—Fig. 81 is a pipette so graduated that when filled up to the mark *a*, *b*, it *delivers*



78. 79. 80. 81.

exactly 100 septems of solution, without reference to what adheres to the inner surface of the glass. The last drop must be blown from the point

by applying the mouth to the upper end of the tube, while the lower end touches the inside of the glass receiving-vessel.



82. 83.

Fig. 82 is a similar pipette, for the delivery of 10 septems of solution. It is useful to have other pipettes to deliver such quantities as 25 or 50 septems, or any arbitrary quantity necessary for a given purpose.

Fig. 83 represents a long narrow pipette, graduated to single septems, of which it may conveniently contain about 20 or 30. The use of this is, to deliver any small quantity of test liquor, such as 1, 2, 5, 10, or any uneven number of septems. See also fig. 87.

To use a pipette.—Hold it by the thumb and middle finger of your right hand; slightly wet the ball of the forefinger; dip the lower end of the pipette into the liquor that is to be measured; apply your mouth to the upper end of the pipette, suck up the liquor, and watch its rise till it is a little above the mark on the neck of the tube; then cease to suck; rapidly slip your fore finger on the upper orifice of the tube, and press it firmly. In going through this process, *remember* that the test liquors are *poisonous* and must not be sucked into your mouth. To prevent this accident, have a steady hand, keep the lower point of the pipette always below the surface of the liquor, and cease to suck at the moment you perceive the liquor above the mark on the neck of the pipette.

Having thus filled the pipette above the mark, hold it steadily before you, fix your eye upon the mark, gently lessen the pressure of the finger on the top of the tube, and let the excess of liquor run out, till the curve formed by its surface touches the mark. Then remove the pipette to the receiving-vessel and deliver its contents. When using the narrow pipette, fig. 83, the liquor should be adjusted to some specific number, such as 5 or 10, and then the number of septems required should be slowly dropped out and counted as they fall. The bottom septem of such a pipette cannot deliver its contents accurately. All quantities must therefore be measured in the middle of the pipette.

By means of these instruments, solutions of acids, alcalies, and salts, may be prepared of any desired degree of strength—*the limit of the strength of each being the solubility of the substance in water at 62° F.* The test atom of any substance can be easily divided into 1000 or any smaller number of equal parts, or any fractional quantity of a test atom may be taken that is desirable for any particular purpose. With the addition of a few other glass vessels, these instruments afford the means of testing the strength and purity of alcalies, acids, and many articles of importance in the arts.

PREPARATION OF STANDARD SOLUTIONS.

I proceed to describe the processes employed to prepare standard solutions of acids and alcalies. These solutions form the basis of the system of centigrade testing, and they must be prepared with great accuracy. The rule to be followed is this: *to form a test liquor of* 100°, *dissolve one test atom of the chemical preparation in so much water as will make a decigallon of solution* at 62° Fahr. The table at page 22 gives the weights of the test atoms. What we have to study now is the practical means of weighing them and bringing them into solution; so as to secure the proper proportion of test and water.

CARBONATE OF POTASH OF 100°.—Expose about 2 ounces of pure carbonate of potash, in a porcelain crucible, to a red heat over a spirit lamp or gas light, to expel water from it. After 10 minutes' ignition remove the crucible from the spirit lamp, and let it cool, closely covered. In the meantime, counterpoise a large thin dry and warm porcelain crucible, containing 864·3 grains in weights. When the ignited carbonate of potash is cool enough to be weighed, remove the weights, and in their place put as much of the ignited salt as restores the equilibrium of the counterpoise. Transfer the weighed salt from the crucible into the decigallon measure, fig. 71, page 97. Add about 10 ounces of pure water, shake the vessel to diffuse the heat, and add more water till the vessel is *nearly* filled up to the mark *a*, *b*. It must then rest till the temperature of the solution sinks to exactly 62° F., which must be tried by a thermometer. When the liquor is come to that temperature, water is to be added by means of a dropping tube, till the measure is completed. This is the case when the engraved line *a*, *b*, coincides with the lower part of the curve formed by the surface of the liquor in the bottle. Cover the mouth of the bottle with a piece of thin writing paper, close it tight with the palm of your hand, and shake the bottle to mix the solution thoroughly. It may then be decanted into a stoppered bottle. It will have the strength of 100°, or be of sp. gr. 1·1047. This solution may be used in preparing test acids of 100°. It is, however, not better than solution of carbonate of soda, and is more expensive.

CARBONATE OF SODA OF 100°.—A normal solution of this salt is prepared precisely in the same manner as the normal solution of carbonate of potash. Expose about 700 grains of the pure anhydrous salt, in a porcelain crucible, to a red heat for ten minutes. As soon as it is cool, weigh out 664·7 grains. Dissolve this in distilled water in the decigallon bottle, fig. 71, dilute the solution nearly to the mark *a*, *b*, bring the temperature of it to 62° F., and then adjust the measure exactly to the mark.

It is of the utmost consequence to prepare this solution with every

attention to accuracy, because it is to form the standard for the strength of your acids, and indirectly of your alcalies, and if your normal solution of soda is inaccurate, all your subsequent analysis of acids and alcalies will be inaccurate in the same degree.

SULPHURIC ACID OF 100°.—Prepare a solution of *carbonate of soda* of 100°, as described under that article. Take of that solution 100 septems, by means of the centigallon pipette, figs. 81 or 86. Put it into a conical mixing jar, fig. 84, or into a wide-necked flask, fig. 78 *g*. Add 12 drops of tincture of litmus. This is most conveniently done by means of a bottle pipette, such as fig. 85. Fill your centigrade alcalimeter with diluted sulphuric acid containing 1 part of oil of vitriol mixed with about 4 parts of water. This mixture is to be made by putting the water into a thin glass flask, *adding the acid to the water gradually*, and allowing the mixture to cool to 62° F. Neutralise the 100 septems of solution of soda with acid poured from the alcalimeter, and ascertain how many septems of acid are required. In doing this the following points are to be attended to carefully. Place a sheet of white paper below the flask or jar, to enable you to see the changes of colour that occur. Add the acid in quantities of about 4 septems at a time. Shake the jar with a circular motion to facilitate the mixture. After a time the blue litmus becomes of a pale claret colour. The jar must now be placed over a spirit lamp until the mixture becomes boiling hot. The acid is then to be slowly added, one or two drops at a time, until the colour of the litmus changes from claret red to a pale scarlet colour. The purpose for which the liquor is made boiling hot, is to expel the carbonic acid gas that is liberated from the carbonate of soda by the action of the sulphuric acid. Carbonic acid gives to litmus a claret or crimson tinge, sulphuric acid gives it a scarlet-red hue. Towards the end of the neutralisation, after every addition of one drop of the acid and agitation of the liquor, a drop of it is to be taken on the fine point of a glass rod and applied to a piece of blue litmus paper. As soon as the alcali is perfectly neutralised, and the liquor contains the least excess of acid, the litmus paper turns red where touched by the wetted glass rod.

84.

85.

86.

The number of septems of the diluted acid that are required to neutralise the soda, show the number of septems of the acid that contain one-tenth part of a test atom of anhydrous sulphuric acid, or that quantity which forms 100 septems of solution of 100°. The experiment

must be *repeated* with great care that you may be quite certain what this number is. I shall suppose it to be 55 septems. In that case, all that it is necessary to do to produce sulphuric acid of 100°, is to put 55 measures of the diluted acid into the test-mixer, fig. 79, page 101, and to add as much water as dilutes the 55 measures to 100 measures.

87.

This dilution is to be effected with certain precautions. Supposing 100 measures of the test-mixer to contain 1000 septems, at first you add about 500 septems of water. Then put in the stopper, and shake the mixture. Afterwards you add more water, at two or three times, until the measure is equal to 990 septems. The mixture is left to cool to the temperature of 62° F., which must be tried by a thermometer. When this temperature is attained, water is slowly added, at first 3 or 4 septems, and the remainder by a dropping tube that cannot deliver above 1 drop at a time, till the measure is exactly 1000 septems. This adjustment requires care, because not one drop of water must be added in excess. If the sulphuric acid of 100°, prepared in this manner, is *pure*, the sp. grav. of the solution will prove on trial to be 1·057. If impure, it will be denser, according to the amount of impurity.

Oxalic Acid of 50°.—A test atom of crystallised oxalic acid weighs 787·5 grains. This quantity of the acid will not dissolve in a decigallon of water at 62° F. We cannot, therefore, prepare oxalic acid of 100°; but, by taking *half* a test atom for a decigallon of solution, we can prepare oxalic acid of 50°. Take 394 grains of clean dry crystals of pure oxalic acid, dissolve them in the decigallon bottle, fig. 71, in water, and dilute the solution, at 62° F., to the bulk of a decigallon. It has, then, a strength of 50°; consequently *two* measures of it will neutralise *one* measure of carbonate of soda of 100°.

The standard solutions of carbonate of soda and of oxalic acid may be considered to be the two bases of the entire system of tests, because all other alcaline and acid solutions are prepared or tested by means of these, and it is a matter of indifference which of these solutions you take for a standard.

Solubility of Acids and Alcalies.—The circumstance that you cannot prepare a solution of oxalic acid of 100°, shows the necessity, in studying the action of equivalent test liquors, of ascertaining the degrees of solubility of those chemical compounds whose frequent recurrence renders them important.

I have observed, at page 102, that solutions may be prepared of any degree of strength, consistent with the solubility of the respective substances in water. Generally speaking, the most soluble substances are the free acids and free alcalies. The limits of solubility of the most important of these, are stated in the tables at pages 106 and 107.

TABLE OF THE SOLUBILITY OF ACIDS.

Temperature 62° F.

Grains of Oxalic Acid, C^2O^3, in one Decigallon.	Grains of Muriatic Acid, H^2Cl^2, in one Decigallon.	Grains of Acetic Acid, $C^4H^6O^3$, in one Decigallon.	Grains of Nitric Acid, N^2O^5, in one Decigallon.	Grains of Sulphuric Acid, SO^3, in one Decigallon.	Test Atoms in one Decigallon.	Septems containing one Test Atom.
				11923·	23·81	42·
				10516·	21·00	47·62
				10015·	20·00	50·
				9514·3	19·00	52·63
				9013·5	18·00	55·56
				8512·8	17·00	58·82
				8012·0	16·00	62·5
				7511·2	15·00	66·67
				7010·5	14·00	71·43
			9132·1	6775·1	13·53	73·91
			8775·8	6509·8	13·00	76·92
			8100·7	6009·0	12·00	83·33
			7425·7	5508·3	11·00	90·91
			6750·6	5007·5	10.00	100·
		6113·6	6473·8	4802·2	9·59	104·3
		5737·5	6075·5	4506·8	9·00	111·1
		5100·0	5400·5	4006·0	8·00	125·
	3427·5	4794·0	5076·5	3765·6	7·52	133·
	3190·5	4462·5	4725·4	3505·3	7·00	142·9
	2734·7	3825·0	4050·4	3004·5	6·00	166·7
	2278·9	3187·5	3375·3	2503·8	5·00	200·
	1823·1	2550·0	2700·2	2003·0	4·00	250·
	1367·3	1912·5	2025·2	1502·3	3·00	333·3
	911·56	1275·0	1350·1	1001·5	2·00	500·5
	455·78	637·50	675·06	500·75	1·00	1000·
427·5	432·99	605·63	641·31	475·71	0·95	1053·
225·	227·89	318·75	337·53	250·38	0·50	2000·
112·5	113·95	159·38	168·77	125·19	0·25	4000·
45·	45·578	63·750	67·506	50·075	0·10	10000·

TABLE OF THE SOLUBILITY OF ALCALIES.

Temperature 62° F.

Grains of Carbonate of Soda, NaO,CO^2, in one Decigallon.	Grains of Carbonate of Potash, KO,CO^2, in one Decigallon.	Grains of Anhydrous Soda, NaO, in one Decigallon.	Grains of Anhydrous Potash, KO, in one Decigallon.	Grains of Anhydrous Ammonia, N^2H^6, in one Decigallon.	Test Atoms in one Decigallon.	Septems containing one Test Atom.
				2125·1	10·00	100·
				1912·5	9·00	111·1
			4779·2	1723·4	8·11	123·3
			4714·4	1700·0	8·00	125·
		2735·9	4136·9	1491·8	7·02	142·5
		2728·1	4125·1	1487·5	7·00	142·9
	5764·9	2599·5	3930·6	1417·4	6·67	149·9
	5185·8	2338·4	3535·8	1275·0	6·00	166·7
	4321·5	1948·7	2946·5	1062·5	5·00	200·
	3457·2	1558·9	2357·2	850·0	4·00	250·
	2592·9	1169·2	1767·9	637·5	3·00	333·3
	1728·6	779·46	1178·6	425·0	2·00	500·
1236·4	1607·6	724·9	1096·1	395·25	1·86	537·6
664·73	864·3	389·73	589·3	212·50	1·00	1000·
332·37	432·15	194·87	294·65	106·25	0·50	2000·
166·18	216·08	97·433	147·33	53·125	0·25	4000·
66·473	86·43	38·973	58·93	21·250	0·10	10000·

These Tables show the limits of solubility of the substances to which they refer. They show what degrees of strength are possible, and what are impossible. You can have sulphuric acid in the state of pure oil of vitriol of 2100°. You may have it as Nordhäusen fuming acid of 2381°. On the other hand, you cannot have oxalic acid of greater strength than 95°. It is curious to see that the solubility of the three mineral acids is nearly as the ratio of 1, 2, 3, namely:—

Muriatic Acid . . .	752°
Nitric Acid . . .	1353°
Sulphuric Acid . . .	2100°

Considerable differences occur also among the alcalies. Ammonia can be made of 1000°, but carbonate of soda not stronger than 186°.

The sixth column of the Tables shows the number of TEST ATOMS of each acid or alcali, that is equivalent to the weights named under the respective heads in the preceding columns. If the decimal point is removed, the numbers in this column express DEGREES.

The seventh column contains information of great importance for the preparation of dilute tests, namely, it states *the quantity, in septems, of each liquor, which contains one test atom*, and it applies equally to all the substances named in the Tables. These numbers are found by dividing 100,000 by the number which represents the degree of each liquor. The mathematical scholar will find the numbers readily by means of a table of reciprocals.

I call this number the ATOMIC MEASURE of a test solution.

PREPARATION OF EQUIVALENT TEST LIQUORS.

AMMONIA.

Ammonia has the remarkable property of possessing the same bulk in all its combinations with water. It neither expands nor condenses in consequence of combining with, or being diluted by, water, in which property it differs essentially from the fixed alcalies and the liquid acids. The atomic volume of water is 16·071429 septems, and its weight 112·5 grains. The atomic volume of ammonia is 42·857143 septems, and its weight 212·5 grains. The volume of H^2O is therefore equal to $\frac{3}{8}$ of that of N^2H^6, or the relation is the same as that of the volumes of elementary gases that constitute the respective compounds. The weight of 1° (the hundredth part of a test atom) of ammonia is 2·125 grains. Its volume at 62° F. is precisely equal to that of 3 grains of water. Every degree of ammonia, added to an aqueous solution, displaces 3 grains of water, reduces the weight of a decigallon of solution to the extent of 3—2·125 = ·875 grain, and diminishes the specific gravity by ·000125. From this principle proceed two important practical rules:—

1. *Given, the Sp. Grav. of a solution of Ammonia, to find its Chemical Strength.*—Deduct the sp. gr. from 1·000000, and divide the remainder by ·000125. The product is the chemical strength expressed in degrees.

2. *Given, the Chemical Strength of a solution of Ammonia, to find its Specific Gravity.*—Express the chemical strength in degrees; multiply it by ·000125, and deduct the product from 1·000000. The remainder is the required specific gravity.

The following table shows the relation between the chemical strength and specific gravity of some solutions of ammonia:—

SOLUTIONS OF AMMONIA.

N^2H^6. Test Atom 212·5 Grains. Temperature 62° F.
Water = H^2O. Test Atom 112·5 Grains.

Specific Gravity of the Solution.	Ratio of N^2H^6 in 1·0000000.	Grains of N^2H^6 in 1000 Septems.	Atoms of N^2H^6 in 1000 Septems.	Septems containing 1 Atom of N^2H^6.
·875	·34694	2125·	10·00	100·
·883333	·32075	1983·3	9·333	107·14
·9	·26984	1700·	8·00	125·
·925	·19691	1275·	6·00	166·67
·95	·12782	850·	4·00	250·
·975	·062271	425·	2·00	500·
·9875	·030741	212·5	1·00	1000·
·99375	·015274	106·25	0·50	2000.
·99875	·003040	21·25	0·10	10000·
·999875	·000304	2·125	0·01	100000·

Determination of the Chemical Strength of Liquid Ammonia.—10 septems of the ammonia to be tried are mixed with 100 septems of water and 12 drops of solution of litmus. Use a wide-necked bottle, fig. 88. The centigrade test tube is to be filled with sulphuric acid of 100°, and the alcali is to be neutralised with all the precautions described in relation to sulphuric acid, page 104, excepting that, as no carbonic acid is present, the mixture does not require to be heated. The operation is finished when the blue mixture suddenly becomes red.

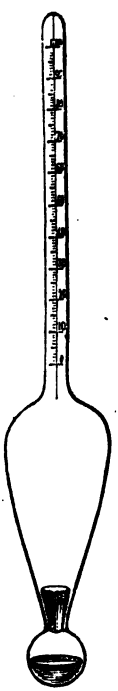
88.

The strongest solutions of ammonia at temperatures not under 62° F. cannot contain above 1000° of ammonia, and most of the solutions liable to be presented for analysis are much weaker. In calculating the *result* of this analysis, the number of septems of sulphuric acid of 100° used to neutralise the 10 septems of ammonia is to be multiplied by 10. Thus, suppose 85 septems of sulphuric acid are required to neutralise 10 septems of the liquid ammonia, then, 85 × 10 = 850, is the strength of the ammonia expressed in degrees. Every 100° of ammonia is equal to 212·5 grains of ammoniacal gas contained in the decigallon of solution.

AMMONIA OF 100°.—Having determined by experiment the *degree* of your solution of ammonia, which I have assumed to be 850°, you have next to find its *atomic measure*, or the quantity of it, which con-

tains 1 test atom of anhydrous ammonia. This, as I have stated in page 108, is done by dividing 100000 by the number that expresses the degree. Now 100000 ÷ 850 = 117·6. Hence, to prepare a solution of 100°, you have to take 117·6 septems of the strong ammonia and dilute it in the test-mixer to 1000 septems. It is then a solution of 100°,

The atomic measure necessarily changes with the chemical strength of every solution. Thus, if you have ammonia of sp. gr. ·9, the chemical strength of which is 800°, then 125 septems, ($= \frac{100000}{800}$) of it is the atomic measure, and will produce 1000 septems of solution of 100° or of sp. gr. ·9875. See table, page 109. The hydrometer indicates the strength of liquid ammonia in a very rough way; for 40 *chemical degrees* of ammonia, mark only 1 degree of a scale like that of Twaddell's hydrometer. I have, however, recently contrived a hydrometer which has a very convenient scale, when such a mode of testing is considered sufficiently precise. I have shown that at 62° F. a decigallon of the strongest ammonia contains 10 test atoms. That makes 100 test atoms in an imperial gallon. The *ammonia-meter* contains 100°, each of which indicates 1 *test atom of ammoniacal gas per gallon of solution.*



89.

This instrument is represented by fig. 89. A very extended table has been prepared to accompany it for the use of dealers in ammonia; it shows the weight of dry ammonia per gallon at every degree, and the corresponding money valuer of each solution.

NITRIC ACID.

DETERMINATION OF THE CHEMICAL STRENGTH OF A SAMPLE OF NITRIC ACID.—*Process.*—Put into a flask of the capacity of 3 or 4 ounces, 100 septems of water. Add 12 drops of solution of litmus, then by means of the graduated pipette, fig. 83, page 102, put into the flask 5 septems of the nitric acid which is to be tested, and shake the mixture, which will have a bright-red colour. Fill the centigrade test tube with solution of ammonia of 100° of strength. Adjust the measure accurately to 0°. To do this easily, you may fill it rather above the mark, grease the lip of the test tube to prevent the liquor flowing down the outside, and pour the extra ammonia back into its bottle, drop by drop, till the proper measure is obtained. The next step is to neutralise the nitric acid with the ammonia, which is to be poured from the graduated tube into the flask in small portions of 2 or 3

90.

septems at a time. After each addition of ammonia, the flask is to be shaken. When the bright-red colour of the acid begins to appear a little fainter, the ammonia must be added in quantities of 2 drops at a time. At last the red colour is suddenly converted into blue, at which point the acid is totally neutralised.

Result.—Having determined how many septems of solution of ammonia of 100° is required to neutralise 5 septems of nitric acid, the degree so found is either to be multiplied by 20, or divided by 5. Suppose 35 septems of ammonia are used, then $35 \times 20 = 700$ septems, or $35 \div 5 = 7$ septems. The former shows the quantity of test ammonia that would be required to neutralise 100 septems of the same nitric acid. The latter shows that the acid is seven times as strong as the ammonia of 100°. Hence it contains 7 test atoms, or 700°, of anhydrous nitric acid per decigallon.

NITRIC ACID OF 100°.—You take nitric acid of any strength, and test its degree in the manner just described. I assume that you find the degree to be 700°, you then calculate the atomic measure, by dividing 100000 by the degree. $100000 \div 700 = 142{\cdot}9$. Hence, 142·9, or say, 143 septems of the strong acid, diluted with water in the test-mixer till it forms 1000 septems, produces nitric acid of 100°.

MURIATIC ACID OF 100°.—Muriatic acid of 100° is prepared exactly in the same manner as nitric acid of that strength. This acid is required for testing limestones, and other substances that produce insoluble salts with sulphuric and oxalic acids.

CAUSTIC POTASH OF 100°—CAUSTIC SODA OF 100°.—A strong solution of caustic potash, or caustic soda, is to be tested in the same manner as the solution of ammonia. The degree having been found by experiment, the atomic measure is calculated, and dilution to 1000 measures is effected in the test-mixer.

TEST LIQUORS OF 50°.—In preparing test liquors of 50° HALF *a test atom* of each chemical substance is to be made into a decigallon of solution. When the substances are solid, such as carbonate of soda, or crystallised oxalic acid, half the atomic weight given in the table at page 22, is to be taken. When they are liquid, half the atomic measures to be taken for dilution to 1000 septems.

GENERAL OBSERVATIONS ON THE PROCESS FOR TESTING THE STRENGTH OF ACIDS AND ALCALIES.—One test acid is sufficient for testing all the alcalies, and one test alcali for testing all the acids. The choice of the test acid lies between sulphuric acid and oxalic acid. The former is much the cheapest of the two, and I think, on the whole, is preferable to the latter. The solution of oxalic acid can be made directly from the pure crystals. The former requires the use of pure carbonate of potash or of soda. But this is a disadvantage which is only felt in the preparation of the first solution, since all others are made by testing with alcali.

The standard alcali may be either ammonia or caustic soda. I find that a solution of the former of 50°, can be kept a considerable time in a cool place without much alteration. The caustic soda does not suffer a loss of strength, from the volatilisation of the alcali, and is preferable on that account. It can only be used, however, with Mohr's form of alcalimeter, fig. 78. None of the alcalimeters which have the spout at the top can be used with caustic soda. The reason is, that those alcalimeters require to have the spout greased with tallow, to hinder the test liquor from running down the outside of the tube, and caustic soda (and caustic potash also) washes the tallow away.

When the standard test solutions and the apparatus are in good order, the analysis of acids and alcalies can be effected with very small quantities of liquor. 5 septems of a strong solution, or 10 septems of a weak solution, is generally enough to operate upon. The best plan for general procedure, is to begin with 5 septems, and neutralise it rapidly. You thus get a rough estimate of the strength of the liquor; after which you repeat the experiment carefully.

In all the preceding examples, I have given the method of calculating results in such a manner as to lead to the preparation of standard solutions of particular *degrees of strength*. But it often happens, in analytical processes, that you want to know the *exact weight* of some component of a substance submitted to examination. I have thrown into the form of a table some examples to show the manner in which experiments of this sort are to be managed. See the Table on pages 114 and 115.

Example.—Neutralise a small quantity,—by weight if solid, or by measure if liquid,—of one of the acids named in the table from 1 to 14, using a test alcali of 100° with an alcalimeter. Observe how many septems of test alcali are required. Let it be 30. Then, under the head of 3 *septems* in the table, and on the horizontal line of the acid submitted to examination, you find a number, which, after the removal of the decimal point, one place to the right hand,—to convert 3 septems into 30,—shows the *number of grains of the acid contained in the quantity that was submitted to the test.* Thus, if the subject of assay was acetic acid, it contained 19·13 grains of anhydrous acid. If it was tartaric acid, the quantity was 24·75 grains of anhydrous acid, equivalent to 28·13 grains of crystallised acid. In like manner, the weight of an alcali can be reckoned from the quantity of test acid required to neutralise it.

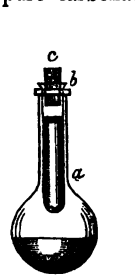
APPLICATION OF THE PRINCIPLES OF CENTIGRADE TESTING TO MERCANTILE AND MANUFACTURING OPERATIONS.—The process of centigrade testing is employed as an easy and rapid method of analysis, to direct the operations of the manufacturing chemist, or to determine the commercial value of his products. It is therefore used to determine the strength of the liquid acids, the purity of carbonate of soda, the bleaching powder of chloride of lime, and to the solution of numerous other technical problems upon which my space does not permit me to

enter into details; but I shall give two or three examples to show the method and importance of such operations.

Testing of Impure Carbonate of Soda.—Commercial carbonate of soda contains water and neutral salts. The object of the analysis is to find how much carbonate of soda it contains. Weigh out *a test atom*, namely, 664·7 grains, of the impure carbonate of soda, and make with it a decigallon of solution, in the manner described at page 103. Then measure off 100 septems of the solution, and test it with sulphuric acid of 100°, in the manner described at page 104. The number of septems of test acid used shows the percentage of carbonate of soda contained in the impure sample.

Testing of Vinegar.—Take 50 septems of vinegar, dilute it with its bulk of pure water, add a few drops of litmus, and neutralise it with test alcali of 100°. Observe the number of septems required, and multiply that number by 2. The product is the strength of the vinegar expressed in degrees.

Testing of Limestone and Marls.—The value of limestone commonly depends upon the quantity of carbonate of lime which it contains. This is true, whether the limestone is to be used as a flux for ironstone in the blast furnace, or to be burnt for mortar or for manure. Marls usually contain from 50 to 80 per cent. of carbonate of lime, the residue consisting of sand or clay. On the contrary, fine English chalk and Irish limestone are almost pure carbonate of lime. The following method of testing limestones is extremely easy, and gives very good results. The flask must be chosen of about the capacity of 6 ounces of water, and with a cylindrical neck, about 6 inches long and 1 inch in diameter. The flask may have the form of fig. 91 *a*, or fig. 92, but it must be thin at the bottom, to bear exposure over a spirit lamp. Fig. 91 *b*, is a tube of thin glass, that fits the neck of the flask pretty close, but slips easily up and down; it is filled with cold water, and stopped by a large cork, *c*. Weigh out on a watch glass, for analysis 62½ grains of the limestone, previously reduced in a porcelain mortar to a fine powder. Put into the flask *a*, 100 septems of muriatic acid of 100°. To do this easily and accurately, use a pipette of the form of fig. 93, graduated to *deliver* 100 septems. Dip this into the prepared acid, adjust the measure, and then transfer the pipette to the flask *a*, without soiling the neck of the flask. Add



91.

92.

93.

TABLE OF TEST EQUIVALENTS, STANDARD

NAMES OF THE ACIDS AND ALCALIES.		1 Septem.	
Acetic Acid, *anhydrous*, . .	$C^4H^6O^3$	·63750	1
— — *hydrate*, . .	$C^4H^6O^3+H^2O$	·75000	2
Citric Acid, *anhydrous*,	$\frac{1}{3}$ of $C^{12}H^{10}O^{11}$	·68750	3
— — *com., cryst.*,	$\frac{1}{3}$ of $C^{12}H^{20}O^{16}$	·87500	4
Muriatic Acid, ...	H^2Cl^2	·45578	5
Nitric Acid, *anhydrous*, . .	N^2O^5	·67506	6
— — *hydrate*, . . .	$N^2O^5+H^2O$	·78756	7
Oxalic Acid, *anhydrous*, . .	C^2O^3	·45000	8
— — *cryst.*, . . .	$C^2O^3+Aq^3$	·78750	9
Sulphuric Acid, *anhydrous*, .	SO^3	·50075	10
— — — *hydrate* . .	SO^3+H^2O	·61325	11
Tartaric Acid, *anhydrous*, .	$C^4H^4O^5$	·82500	12
— — — *cryst.*, . . .	$C^4H^4O^5+H^2O$	·93750	13
Carbonic Acid, ...	CO^2	·27500	14
Ammonia, ...	N^2H^6	·21250	15
Potash, *anhydrous*, . . .	KO	·58930	16
— Carbonate, ...	KO,CO^2	·86430	17
Soda, *anhydrous*, . . .	NaO	·38973	18
— Carbonate, ...	NaO,CO^2	·66473	19
— — *cryst.*, ...	NaO,CO^2+Aq^{10}	1·7897	20

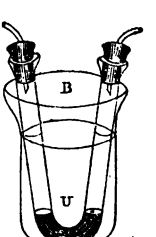
the pulverised limestone gradually to the muriatic acid, agitating the mixture after every addition of powder. When the powder has been all added, if any of it sticks about the neck of the flask, it must be washed down into the acid by means of a washing-bottle. Put the tube *b* into the flask, and apply heat to the flask by means of the spirit lamp. This completes the action of the acid on the limestone and expels the disengaged carbonic acid, which lifts up the tube *b*, and escapes. The cold water is intended to condense any vapour of muriatic acid that may be produced by the heat, and so prevent its escape from the flask. When the liquor has been raised to a boiling heat, the flask may be removed from the lamp. The outside of the tube *b* is to be washed by the spirting bottle, and the washings added to the contents of the flask. Add 12 drops of solution of litmus to the mixture, which will become red, and then by means of a centigrade test tube, add solution of ammonia or soda of 100° until the mixture turns blue. *Result.*—Every septem of ammonia required to be added to neutralise the mixture in the flask, indicates 1 per cent. of impurity in the limestone.

SOLUTIONS, ONE TEST ATOM IN A DECIGALLON.

	2 Septems.	3 Septems.	4 Septems.	5 Septems.	6 Septems.	7 Septems.	8 Septems.	9 Septems.
1	1·275	1·913	2·550	3·188	3·825	4·463	5·100	5·738
2	1·500	2·250	3·000	3·750	4·500	5·250	6·000	6·750
3	1·375	2·063	2·750	3·438	4·125	4·813	5·500	6·188
4	1·750	2·625	3·500	4·375	5·250	6·125	7·000	7·875
5	·9116	1·367	1·823	2·279	2·735	3·190	3·646	4·102
6	1·350	2·025	2·700	3·375	4·050	4·725	5·400	6·076
7	1·575	2·363	3·150	3·938	4·725	5·513	6·000	7·088
8	·900	1·350	1·800	2·250	2·700	3·150	3·600	4·050
9	1·575	2·363	3·150	3·938	4·725	5·513	6·300	7·088
10	1·002	1·502	2·003	2·504	3·005	3·505	4·006	4·507
11	1·227	1·840	2·453	3·066	3·680	4·293	4·906	5·519
12	1·650	2·475	3·300	4·125	4·950	5·775	6·600	7·425
13	1·875	2·813	3·750	4·688	5·625	6·563	7·500	8·438
14	·550	·825	1·100	1·375	1·650	1·925	2·200	2·475
15	·425	·6375	·850	1·063	1·275	1·488	1·700	1·913
17	1·179	1·768	2·357	2·474	3·536	4·125	4·714	5·304
16	1·729	2·593	3·457	4·322	5·186	6·050	6·914	7·779
18	·7795	1·169	1·559	1·949	2·338	2·728	3·118	3·508
19	1·329	1·994	2·659	3·324	3·988	4·653	5·318	5·983
20	3·579	5·369	7·159	8·949	10·74	12·53	14·32	16·11

Thus, if 20 septems of ammonia are used, the limestone contains 80 per cent. of carbonate of lime. The reasons are obvious: 62½ grains of carbonate of lime, 100 septems of acid of 100°, and 100 septems of ammonia of 100°, all contain the $\frac{1}{10}$ part of a test atom of the respective reagents, provided all are pure. Hence, if carbonate of lime is deficient, the ammonia supplies its place and indicates the quantity.

Testing of Ammonia.—In the examination of impure salts of ammonia, used for manure and other purposes, it is necessary to ascertain the quantity of ammonia. The impure compound is heated in a flask with a solution of caustic soda, which disengages ammonia in the state of gas. To determine the quantity of this ammonia, you collect it in such an apparatus as is represented by fig. 94, where U is a bent tube containing 100 septems of acid of 100°, and B a glass with cold water for condensation. Such a quantity of the ammoniacal compound must be operated upon as will liberate a smaller quantity



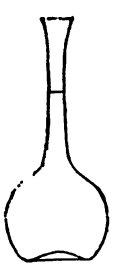
94.

of gas than 100 septems of acid of 100° can absorb. The table at page 114, column 1, line 15, shows, that that quantity of ammonia is 21¼ grains. At the end of the distillation, the excess of acid must be neutralised by test alcali of 100°, and the number of septems of test alcali being deducted from 100, the residue shows the equivalent of ammonia. Thus, if 30 septems of alcali are required, the ammonia must have neutralised 70 septems of test acid, and according to the table at page 115, column 7, line 15, that indicates the presence of 14·88 grains of ammonia.

In the analysis of guano, the nitrogen it contains is converted into ammonia by ignition with soda and lime; but the ammonia, when disengaged, can be estimated in this manner.

Miscellaneous Experiments with Equivalent Test Liquors.

A great variety of salts can be quickly and economically prepared in small quantities for examination by tests, &c., by this process, which is therefore strongly recommended to students. Solutions of the principal acids, alcalies, and alcaline carbonates, all of 100° or of 50° of strength, are first prepared by the processes described under the respective articles, setting out with the normal solution of carbonate of soda, described at page 103. Solutions of the principal salts should also be prepared of 100°, 50°, or 10° of strength. But as, of such solutions, a student will not require so large a quantity as a decigallon, he should be provided with a centigallon (100 septems) test-mixer of the form shown by fig. 80, page 101, or with a bottle like fig. 95, which holds 100 septems when filled up to a mark on the neck. To prepare solutions of 100° with this instrument, $\frac{1}{10}$ part of a test atom of each salt is required for 100 septems of solution. That is to say, the numbers in the table at page 22 require the decimal point to be moved one figure to the left. Thus, 152½ grains of crystallised chloride of barium will give 1 centigallon of solution of 100° at 62° F.—A bottle of this sort, graduated to 250 septems, requires ¼ of a test atom of the salt, and gives 4 fluid ounces of solution.—



95.

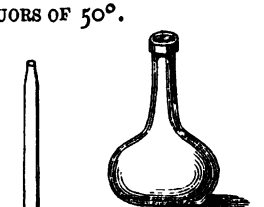
When the student has prepared a series of such solutions, he can proceed to make a series of other salts as follows:—By adding 10 septems of sulphuric acid of 100° to 10 septems of solution of potash of 100°. The measure is best effected by a pipette, graduated so as to *deliver* 10 septems of liquid, independently of what adheres to the tube, fig. 82. The mixture may be made in a capsule of glass or porcelain, in which the product can be evaporated for the purpose of crystallisation. No filtration is necessary, because the liquors are all considered to be pure. The above mixture yields, if the operation is correctly performed, neutral sulphate of potash, the quantity of which should agree with the indications of the table at page 114. 10 septems of sulphuric acid of 100°. contain 5·0075 grains of anhydrous acid, and the same quantity

of solution of potash of 100° contains 5·893 grains of anhydrous alcali. The sulphate of potash produced by their mixture should therefore weigh 5·0075+5·8930 = 10·9005 grains. See the atomic weight of sulphate of potash, in the table, page 28.—Other salts may be produced in a similar way. If 10 septems of muriatic acid of 100° are put into a test tube, and 6¼ grains of pure calcareous spar are added, and the liquor is boiled when the effervescence ceases, the muriatic acid should be entirely neutralised, and the liquor contain neutral chloride of calcium. For 10 septems of acid of 100° is the 100th part of a test atom, and 6¼ grains of calc spar is also the 100th part of a test atom, and these are therefore equivalent quantities.—If the resulting solution of chloride of calcium is diluted with water to the bulk of 100 septems, then the solution will be of 10° of strength, and 10 septems of it should be exactly precipitated by 10 septems of solution of nitrate of silver of 10° of strength.

In the same manner 10 septems of nitric acid of 100° should dissolve the 100th part of a test atom, namely, 4 grains, of metallic copper, producing the 100th part of a test atom of nitrate of copper. The various compounds that may thus be formed can be evaporated and crystallised, or preserved in the liquid state, or be tested by the reagents, or be converted by double decomposition into other salts. Thus 10 septems of chloride of barium of 100° mixed with 10 septems of sulphate of soda of 100° will be totally decomposed, producing the 100th part of a test atom of insoluble sulphate of barytes, and the 100th part of a test atom of soluble chloride of sodium. By filtration, washing, and evaporation to dryness, both may be obtained separately in the solid state. It is quite evident that a vast number of accurate experiments may thus be performed with facility and great economy.

Experiments with Test Liquors of 50°.

These experiments are to be performed in the manner just described. 10 septems of each liquor are to be measured by means of a graduated pipette, fig. 96. The liquors are to be mixed in a glass flask, fig. 97, or a beaked tumbler, fig. 98, both thin enough at the bottom to bear heating over a spirit lamp. When there is a precipitate, it is to be collected on a paper filter placed in a glass funnel, fig. 99, and to be washed with pure water, by means of the washing-bottle, fig. 100, the water from which is expelled by the tube *b*, when you blow into the tube *a*. The washings are to be added to the solution, which is to be poured into a small porcelain evaporating basin, and to be evaporated as directed at page 55, that the



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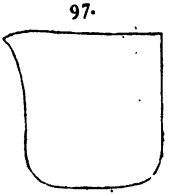
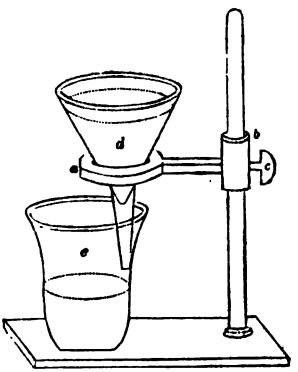


98.

salt it contains may crystallise. If you possess a microscope, a drop of the solution with some of the precipitated salt, should be placed on a glass slider and examined under the microscope. Sulphate of lime



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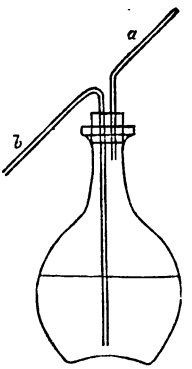

100.

and other precipitates often show very beautiful and characteristic crystals. A drop of the filtered solution after concentration by heat should also be examined thus, when the forms of the different salts will be distinctly perceptible.

Experiments on the Composition of Salts.

1. Mix sulphuric acid with ammonia. Evaporate and crystallise. The product is sulphate of ammonia.

2. Mix sulphuric acid and soda. Evaporate and crystallise. Product, sulphate of soda.

3. Mix sulphuric acid and potash. Crystallise. Product, sulphate of potash.

4. In the same way, muriatic acid and ammonia produce chloride of ammonium.

5. Muriatic acid and soda produce chloride of sodium.

6. Muriatic acid and potash produce chloride of potassium.

Nos. 5 and 6 can be crystallised by slowly evaporating the water.

7. Nitric acid and ammonia produce nitrate of ammonia. Crystallise.

8. Nitric acid and soda produce nitrate of soda. Crystallise.

9. Nitric acid and potash produce nitrate of potash. Crystallise.

10. The salts produced by mixing caustic alcalies with acids can also be produced by mixing the carbonates of the alcalies with acids, the carbonic acid being discharged in the state of gas.

11. When equal measures of an acid and an alcaline test solution of the same degree are mixed together, the resulting solution has only *half the degree* of the components. 1000 septems of sulphuric acid of 100°,

and 1000 septems of soda of 100°, produce 2000 septems of sulphate of soda of 50°; because there is present in all only 1 test atom of sulphate of soda, and that is dissolved in 2000 septems of solution.

Double Decomposition of Salts.

In these experiments use 10 septems (or, if you prefer it, 25 septems) of each liquor. Boil the mixture and let it cool. The precipitates are to be separated by filtration, and the salts remaining in solution are to be crystallised. Double decomposition of salts, effected by equivalent quantities of solution, is rarely quite complete. Sometimes part of one of the original salts is carried down by the precipitate: sometimes part of what should precipitate remains dissolved in the mother liquor. Nevertheless, this set of experiments gives very striking and instructive results.

12. Mix sulphate of soda and chloride of calcium. Boil. Products, sulphate of lime crystallised, and chloride of sodium in solution.

13. Mix sulphate of soda and nitrate of lime. Products, sulphate of lime crystallised, and nitrate of soda in solution.

14. Mix sulphate of soda and chloride of barium. Products, sulphate of barytes in powder, and chloride of sodium in solution.

Experiments with Phosphate of Soda of 10°.

15. Mix 5 measures of this solution with 1 measure of chloride of calcium of 50°. Product, phosphate of lime precipitated and chloride of sodium in solution.

16. Mix 5 measures of the phosphate of soda of 100°, with 1 measure of nitrate of lime of 50°. Product, phosphate of lime precipitated and nitrate of soda in solution.

These experiments give examples of the manner in which the nature and relations of *saline manures* may be explained in schools where agricultural chemistry is taught.

The teacher can not only show the substances in their crystallised condition, and say, "This is nitrate of soda—this is sulphate of soda—that is gypsum, &c," but he can demonstrate the properties of the proximate elements of these salts; he can exhibit experimentally the differences between acids and bases, and can use the tests by which the individuals of each class are severally identified. He can then with facility and certainty *compose the salts* before the eyes of the pupils, making common salt and nitre, and glauber's salts and sal-ammoniac, by the mixture of corrosive acids and alcalies; and producing insoluble gypsum and bone-earth by the mixture of limpid solutions. It cannot be doubted that, in agricultural schools, experiments of this practical kind, made, as they could be made, thoroughly intelligible to the pupils, would be productive of very beneficial results. The *nature* of the saline manures would be better comprehended, and the *cheating*

practised by dealers in manures, would be in a great measure prevented. No young farmer who had performed, or had seen performed, the analytical experiments described in the preceding pages, would ever pay the price of guano for a mixture of brickdust and spent bark, or even pay the price of good saltpetre for a mixture containing forty per cent. of common salt; examples of agricultural economy which stand on record, and are perhaps not unfrequent. Teaching of this sort might induce farmers to let their sons remain at school a little longer than they are now contented to do for the sake of acquiring what they are apt to regard as unmarketable book learning.

Experiments with these equivalent test liquors might be multiplied to an indefinite extent. Besides those which depend upon the action of two such liquors, you can, on the one hand, take a given quantity of a test acid, say 10 septems ($\frac{1}{70}$ test atom), and act upon it with various metals, oxides, carbonates, &c., and ascertain the quantity of salt produced; and, on the other hand, you can with the same quantity of a test alcali, examine the saturating powers of various acids, and the quantity of salt thus produced. With little trouble and with little expense, you can in this manner carry out a very extensive series of chemical researches. You do not, indeed, make conflagrations and explosions at every step, you miss the thunder and lightning of the lecture-room, you escape from the hilarity of holiday chemistry; but you gradually acquire the knowledge, the resources, and the power of the philosophical chemist.

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